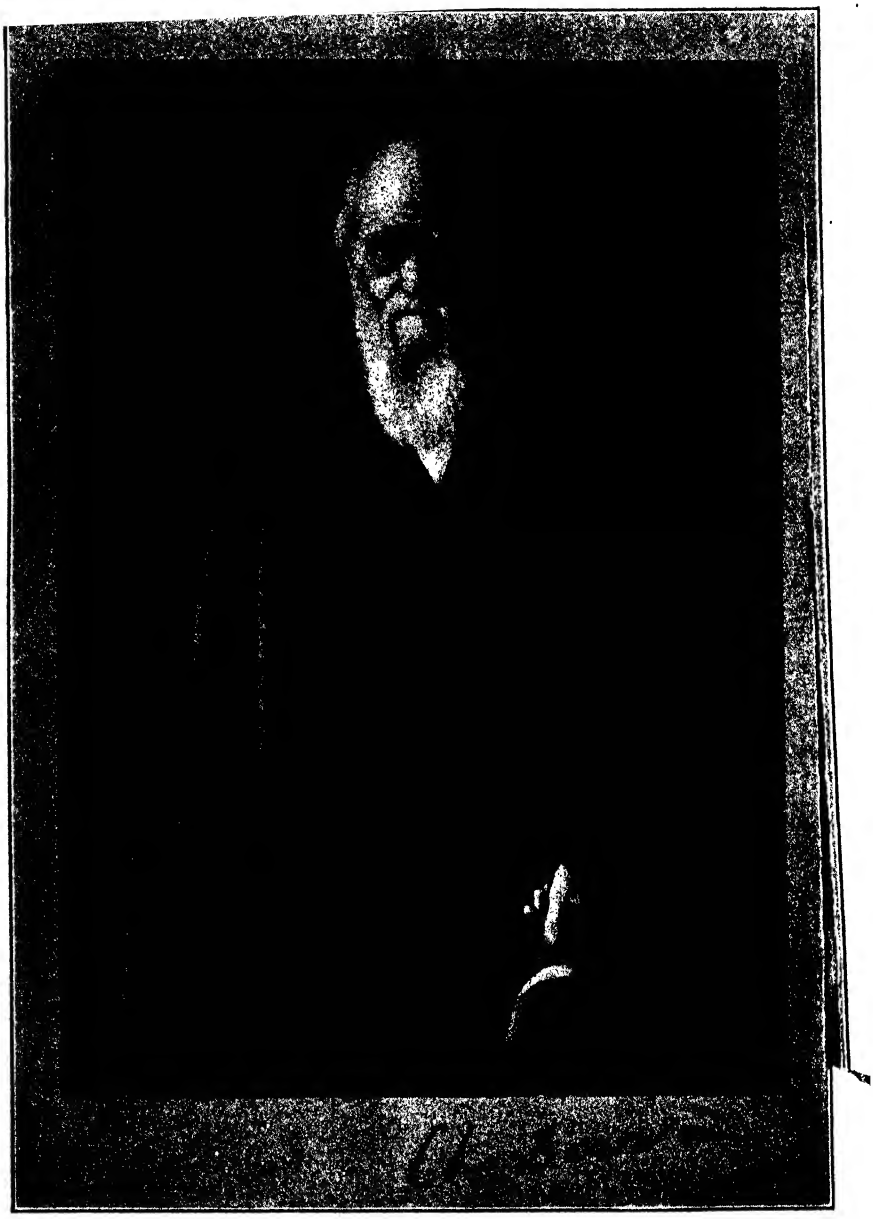
# A PICTURE BOOK OF EVOLUTION



Charles Darwin
From a painting by Hon. John Collier
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# A PICTURE BOOK OF EVOLUTION

ADAPTED FROM THE WORK OF THE LATE

DENNIS HIRD, M.A.

BY

SURGEON REAR-ADMIRAL

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*Fellow of the Zoological Society and Member of the British Astronomical Association, Late Fellow of the Chemical Society and of the Royal Anthropological Institute*

WITH A FOREWORD BY

SIR ARTHUR KEITH,

M.D., D.Sc., LL.D., F.R.C.S., F.R.S.

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# FOREWORD

By Sir Arthur Keith, M.D., F.R.S.

MY friend Surgeon Rear-Admiral C. M. Beadnell has asked me to write the Foreword for this book. He is under the impression that my name is better known than his to the reading public. If this is so, then it is time that this impression should be altered. Naval surgeon by profession, Rear-Admiral Beadnell has been known to many of us for a long time as an able student of evolutionary problems. In bringing up to date, and indeed in rewriting, many chapters of the well-known work by the late Mr. Dennis Hird he has rendered a real service to the Cause of Evolution.

He and I believe in Evolution, not as a theoretical doctrine, but as a practical way of looking at all manifestations of life—of politics, of history, of all that pertains to the physical universe. The reader may ask: Is there anyone to-day who does not believe in Evolution? If readers will look into their real beliefs, they will probably find that, although they accept Darwinism as truth, they think of it as a doctrine that was true in past times, but has in these modern days ceased to be operative. They are really not convinced evolutionists; they do not realize that the law of Evolution is going on in them and around them, shaping human destiny during every hour of the day. Most of us are willing to render Charles Darwin a lip service, but only few of us realize that every thought we formulate and every act we perform or fail to perform alter to an appreciable degree the course of events—the course which Evolution is taking in human affairs. We often boast of modern progress, forgetting that progress is in most cases merely another name for Evolution.

The main aim of this book is to bring home to its readers that Evolution is not only a theoretical doctrine, but is also a practical issue. Hence the instances selected to illustrate the truth of Darwin's teaching have been chosen from common things—things with which all are familiar—in the streets, homes, and waysides of this goodly earth of ours and in the star-

spangled heavens above. The examples chosen have been of a kind that permit the illustrator's art free scope, and help readers to understand how potent and prevailing is the law of Evolution. This book itself, in the form now given to it, has undergone a true revolutionary metamorphosis; Rear-Admiral Beadnell has adapted it to meet modern needs, and has thus rendered a service to all—both young and old, who are interested in the Cause of Evolution.

ARTHUR KEITH.

*June*, 1947.

# PREFACE TO THIRD EDITION

### By the Compiler

ABOUT a quarter of a century ago the present writer was one of a London audience attending a course of Lantern Lectures upon the absorbingly interesting subject of Evolution delivered by that fascinating and popular lecturer, Dennis Hird, M.A., Principal of Ruskin College, Oxford. The appreciative reception, both in London and the provinces, accorded Mr. Hird's lectures made obvious the desirability of issuing them in book form. This was carried out by Messrs. Watts and Co., and the success of the first edition of Hird's *Picture Book of Evolution* soon rendered necessary the appearance of a second. As Mr. Hird died in 1920, a continued demand for the work has not, until the present issue, met with response. When Messrs. Watts asked me to undertake the task of revising the book, I confess to having had serious misgivings as to my competency to do so, in view of the enormous strides taken by Science in its several branches during the last two decades. Shortly after commencing the work it became apparent, both to the Publishers and myself, that revision in the ordinary sense was impracticable, and that if the book was to rank as an up-to-date illustrated statement of the ever-urgent message of Evolution it would have to be entirely recast. To such a degree has this had to be effected that the *Picture Book of Evolution* has now become not unlike that woodman's axe that was successively fitted with a new blade and a new haft. All the chapters have been re-written, and an Index, Appendices, and many modern pictures and illustrations have been added, though, wherever expedient, the pictures chosen by Mr. Hird have been retained. But the woodman's axe, despite its renewal, was still, in a sense, the old and trusty implement of its owner; and so likewise this book still preserves that individuality which was imparted to it by the hand of Dennis Hird.

I take this opportunity to express thanks to the Publishers' Staff for much generous help in connection with the book.

Lastly I must mention my indebtedness to my wife for the constant assistance she has given me throughout in the checking of the proof-sheets and the preparation of the Index.

CHARLES M. BEADNELL.

*Old Stacks, Ringwood, Hants.*
*May*, 1932.

# PREFACE TO FOURTH EDITION

## By the Compiler

THE call for a further edition of this book is evidence of the unflagging interest taken by the intelligent section of the public in the great truths of Evolution, whether these pertain to man or ape, to animals or plants, to extra-galactic universes, stars and planets, to crude matter and radiant energy, or to molecules, atoms, and sub-atoms.

It has seemed to me that, in a book carrying the title this does, the " picture " is a most important component and that it should convey to the reader something more than the name and general appearance of the animal or other object depicted. With this end in view most of the captions have been considerably amplified.

So great have been the strides of Science in its advance that ever since the last issue of the *Picture Book of Evolution* startling and revolutionary discoveries have been made, more especially in the behaviour and structure of such macroscopic systems as our own Milky Way and other colossal systems outside it, and of such ultra-microscopic systems as lie " beyond the atom." This has necessitated a certain amount of revision as well as the addition of a considerable quantity of fresh material.

I feel confident that the late Mr. Dennis Hird would have warmly welcomed the incorporation of these further proofs of Evolution in the *Picture Book.* Whatever merits the two editions of this work that have passed through my hands may possess, the credit for the conception and creation of the book must be given to Dennis Hird; he laid its firm foundations, modelled and built up the greater portion of the edifice; my function has been to add a few rooms and modernize the whole building.

Charles M. Beadnell.

*Wayside, Steep, Petersfield, Hants.*
*June,* 1947.

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# A PICTURE BOOK OF EVOLUTION

## CHAPTER ONE: SIMPLE EXAMPLES OF EVOLUTION

IF we wish to know how the earth was formed, and how all the plants and animals came upon it, we must let the men of science teach us the wonderful things which they have found out. For thousands of years men have been inquiring into the history of the earth and all its inhabitants and they have discovered very marvellous things.

One of these discoverers was Charles Darwin. He and Alfred Russel Wallace separately discovered the same great underlying method of Evolution—Natural Selection. Darwin and Wallace published a short account of this in the journal of the Linnean Society on July 1, 1858. Darwin's famous book *The Origin of Species* appeared on November 24, 1859. This book has revolutionized thought and killed many errors.

We are now able to look at the world and all " that therein is," and see fairly clearly how it has come to pass. The whole process is called Evolution, which means unrolling. With regard to plants and animals, Evolution teaches that they have come by descent from early forms which were so simple and tiny that they cannot properly be described as either the one or the other; they lived millions of years ago, before living things had divided into the two classes we call " plants " and " animals," each of which has developed on its own line.

In the history of our earth there is nothing more wonderful than the fact that man has discovered so many of the laws by which the earth and its inhabitants are governed. If we begin with quite simple cases, we shall be able to see for ourselves the working of some of these laws.

From a speck of matter so small that we cannot see it without a magnifying glass there may arise, by gradual growth, a giant tree or a huge animal. The acorn in Fig. 1 is of the kind from which grow our oak trees. If I were to ask anyone to bring a party of friends and sit under the shadow of this acorn, I should cause much laughter. But if we could wait 200 years, till the acorn had produced a full-grown oak, nothing would be more natural than to seek shelter under it on a warm summer day. This teaches us one of the great laws of the world—namely, the law of growth. There

is a time when a very little child could carry the acorn and the germ within it; but after centuries of growth it becomes so large that the strongest animal in the world could not carry it. If we are to understand how all the living things in the world have come, we must always bear in mind this law of growth. The word "law" is used here and elsewhere throughout the work, not as implying the existence of a "law-maker" or "law-giver," but in the sense defined by Isaac Newton and Henri Poincaré—viz., as the necessary relation between the present state of the universe and its immediately antecedent and subsequent states.

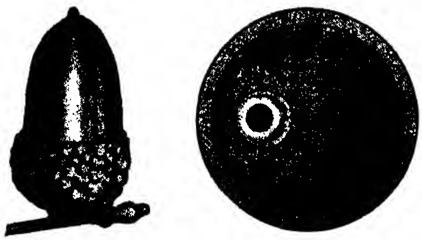


FIG. 1.—An Acorn and its Germ.

The acorn shown on the left is an inch in length and weighs less than an ounce. On the right is its germ-cell—a tiny blob of jelly less than 1/100th of an inch in diameter, about the size of a full-stop but here enormously magnified. Though the two together do not weigh an ounce, there can grow from them, in 200 years, an oak tree 60 feet high and weighing many tons.

Let us take a familiar object—the bicycle—and we shall discover another law.

Fig. 2 shows us the nearest approach to a bicycle, such as was used in 1820. If men were to use it now we should laugh, for it seems so grotesque. The rider pushed the machine with his toes, and then rode as long as he could before he gave it another push.

But improvements were made, and nearly fifty years afterwards men used the old "bone-shaker," which you see in Fig. 2. It was an instrument of torture, without such luxuries as gearings or ball-bearings or pneumatic tyres; but it had pedals, and it was not a plaything. It was a great advance on the velocipede.

After the bone-shaker had been in use a long time someone made an improvement, and men rode the "Humber Spider." This machine had an immense fore wheel and a very small back wheel. The rider had to mount by a step, and to us it would seem not only a dangerous, but an absurd means of progression. Then followed the well-known "penny-farthing" bicycle with its yet larger front, and smaller hind wheel, as you can see in Fig. 3.

But every year brought improvements. One inventor found out that we need not have a huge wheel in front, with a sort of little lap-dog running behind; another thought of ball-bearings; another of the cushion tyre, and then of the pneumatic, and so on, till it was possible to buy a free-

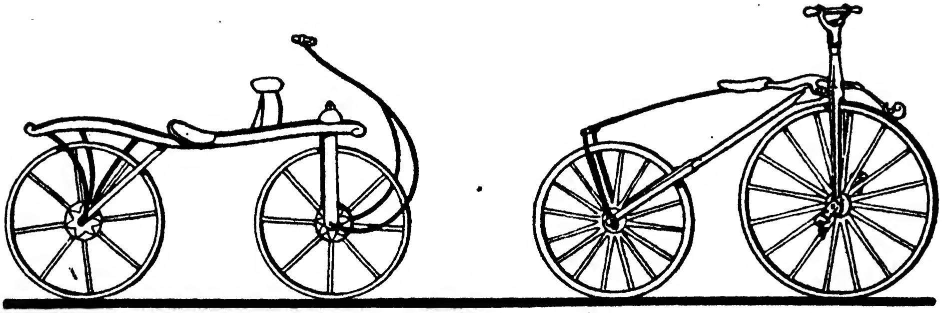


FIG. 2.—The Dandy, or Hobby-horse, A.D. 1820. The Bone-shaker, A.D. 1870.

wheel with low, medium and high gears, such as you see in Fig. 3, which is not only beautiful and comfortable, but enables the rider to travel faster on the level and to climb steeper hills.

Then the inventors caught up the idea of riding without toil, and produced motor-vehicles (Figs. 4 and 5).

The next great step was the conquest of the air by aeroplanes (Fig. 6).

Now, I have taken these few examples of machines with which everybody is familiar, because they will help us to understand the evolutionary process.

The account given of the bicycle might be called a short history of its evolution. Some of the steps of this evolution are clear to us:—

1. The earliest form was so simple and rude as to be almost useless, so that form did not remain long.

2. The improved machines drove the others out of use.

If you were to try to buy a " hobby-horse " or a " bone-shaker," you

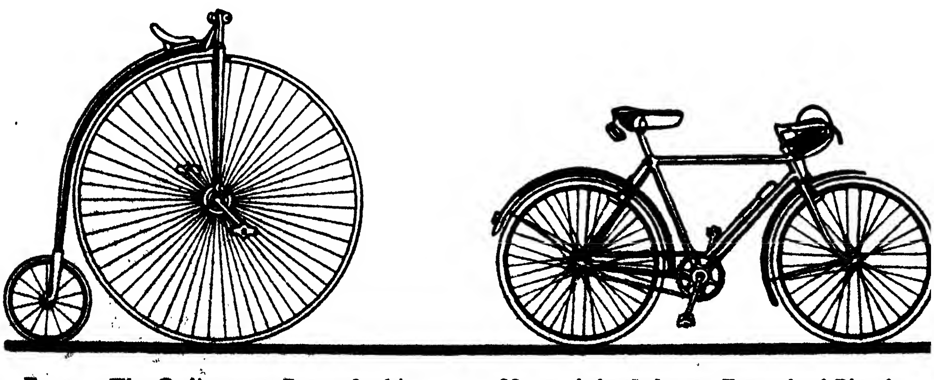


FIG. 3.—The Ordinary or Penny-farthing, A.D. 1883, and the Safety or Free-wheel Bicycle.

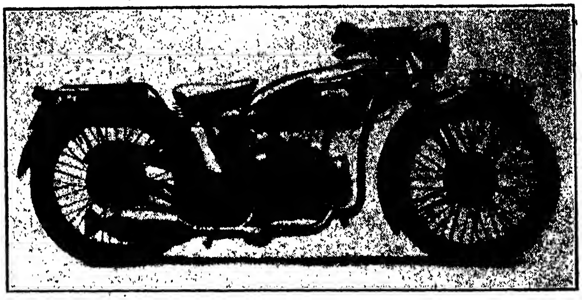


FIG. 4.—A Modern Motor Cycle.

would soon learn that they are no longer in the market, and in most towns you would not find one at any price. The steady march of improvements has banished them. This is what we mean when we say that anything has become extinct. In a practical world the better banishes the inferior. It is indeed a form of "the survival of the fittest."

These two laws are of great importance, and we shall meet them again in considering Evolution.

After the very familiar steps shown by the bicycle and other means of transport we may take another example.

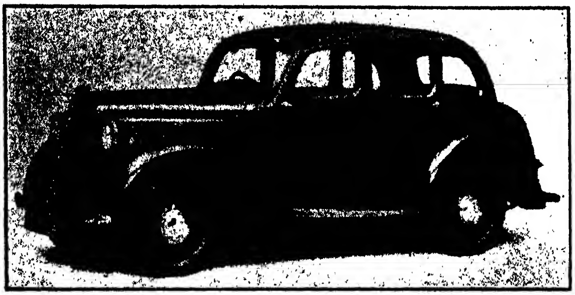


FIG. 5.—The Morris Ten Four-Seater Saloon.

In Fig. 7 we see a weapon which seems to us to belong so entirely to the past that it has left no trace in our modern life. Yet this is not so. Men lived many thousands of years before they dis-

FIG. 6.—The Handley-Page "Hermes."

covered this deadly weapon. It was a marvellous discovery in its time, but you can find no soldiers armed with bows and arrows in any modern army.

The bow and arrow gave rise to two wonderful inventions of our modern life; we see them in Figs. 9 and 10.

Few people at first see any connection between a piano and a rifle. They constitute a fine example of two very different instruments having been developed from one.

Fig. 7.—Veddahs of Ceylon with Primitive Weapons of War.

When the hunter or warrior pulled the string close to his ear he heard a rich twang as the string vibrated. So he began to develop instruments for producing sound by arranging two or three strings in a simple way. For ages these were improved, till at last we have our modern piano—an arrangement of strings.

But a sterner use of the bow and arrow was to kill. Man is, unfortunately, a killing animal. He improved the arrow and added strength to his bow, till the English archers were the dread of their foes. Then the invention of gunpowder furnished a new force which propelled the missile independently of muscular labour. The earliest guns were simple, but constant improvements have given us the efficient modern rifle and Tommy Gun. The steps of the evolution of the modern weapon, an example of which is the battleship shown in Fig. 8, can be seen in the Pitt Rivers Museum.

Now, it must be granted that Evolution has brought about modern bicycles, pianos, and rifles; yet the critic may ask: "Is there any such process in nature to be seen in the known history of living things?" There is.

FIG. 8.—H.M.S. Rodney, with its complex machinery, mechanical appliances, and deadly weapons of precision, is the modern descendant of an ancestral "dug-out" used by savage tribes in their warfare against neighbouring enemy tribes.

We will take by way of illustration the feet of the horse, an animal whose evolution has been worked out with extraordinary detail by Marsh, Matthew, Lull, and others. All palæontologists (*palaios*, old; *onta*, existing things; *logos*, science) are agreed that the main drama of the horse's evolution was enacted in N. America; and yet, curiously enough, this animal became extinct throughout the whole of America in the middle of the Pleistocene period, as shown by the diagram on page 10.

The bones of the feet shown in Figs. 11 and 12 tell one of the most marvellous stories. The figures depict the celebrated fossils found by Professor Marsh in New Mexico and placed in the Yale Museum. (When the whole or part of any once-living thing has been preserved in the rocks it is called a *fossil* —a thing dug out.) The figures just referred to deal principally with the fore-foot, or "hand."

FIG. 9.—A Chappell Grand.

Beginning at the left side of Fig. 11, we will work our way upwards through the fossil-bearing layers and study the horse-like animals we meet *en route.*

The first definite horse-ancestor appears in the lower Eocene, and for that reason it has been christened *Eohippus* or dawn-horse (*eos*, dawn; *hippos*, horse). It was a small animal standing 12 inches high, about the size of a terrier. Its hand not only bore four perfect fingers, each ending in a little hoof or nail, but also the vestige of the thumb or first digit (*a*, Fig. 11). This shows that the creature sprang from a five-fingered stock. The foot carried but three toes, though the remnant of the little or fifth toe can be seen (*b*, Fig. 11) lying as a " splint-bone " against the side of the fourth. The first or great toe has entirely disappeared.

A close relation of this little animal, and not unlike it in appearance, dwelt at that time in Europe and Asia, its remains having been found in the London Clay layers. This animal, *Hyracotherium* (Fig. 72, page 73), is the most primitive horse-like form of the Old World, and in all probability arose, as well as its cousin *Eohippus*, from some common ancestor of the Cretaceous no larger than a rat and bearing five digits on each limb.

Passing up into the middle Eocene, we come across a direct descendant of *Eohippus* called *Orohippus*, the Mountain horse, a slightly larger animal about 13½ inches high. This creature's superiority—from the specialized horse view-point—over predecessors is shown by the loss of the fifth toe and thumb and the shortening of the outer or little finger. *Orohippus* gave rise, in the upper Eocene, to *Epihippus*, which stood about 14 inches high; its hand still possessed four fingers and its foot three toes, but the middle digit of each showed signs of outgrowing all the others and of taking over, so to speak, their work.

From *Epihippus* evolved, in the lower Oligocene, *Mesohippus*—a creature

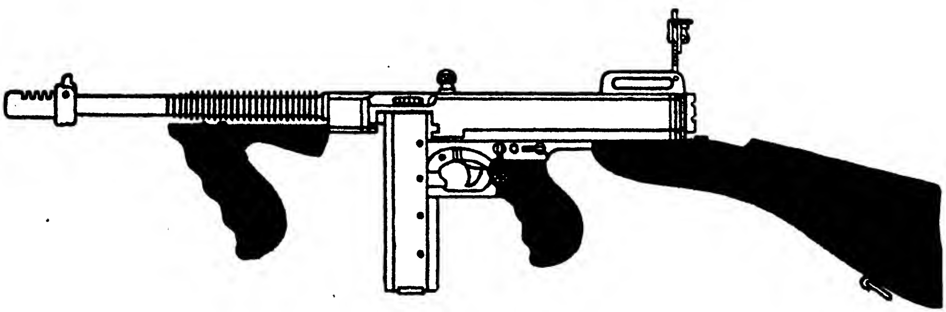
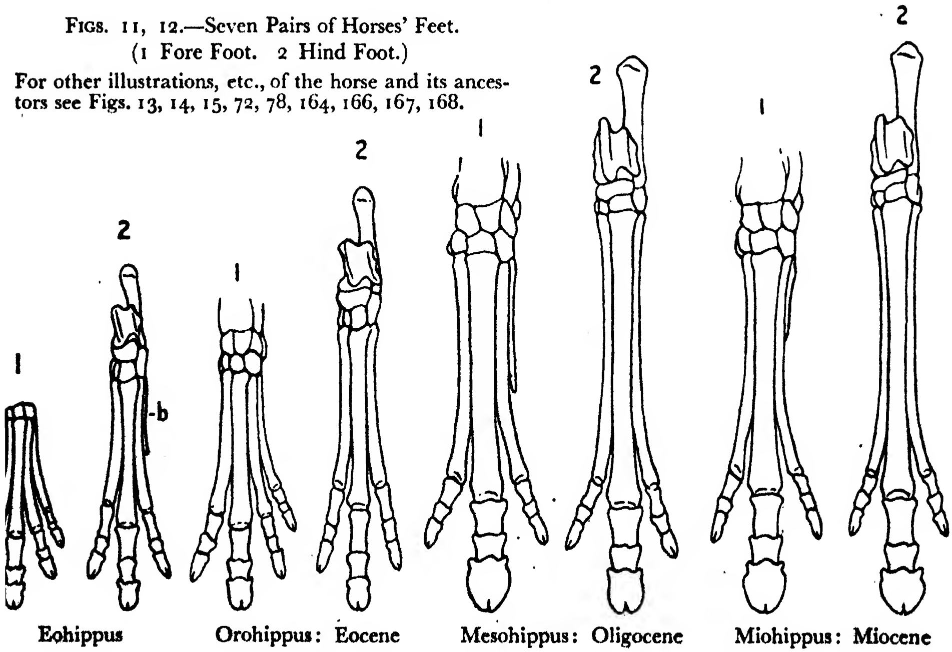


FIG. 10.—The ·45-inch Thompson Submachine Gun (Tommy Gun). Again, as we saw in the case of the battleship, this quick-firing weapon, originally designed in U.S.A. for police work, and firing 100 to 1,500 rounds a minute, may be regarded as one of the modern descendants of the bow and arrow of ancient savages.

that averaged the size of a retriever: *M. bairdi* standing 18 inches, *M. intermedius* 24 inches high. It had three fingers and a splint-like vestige of the little finger. Although three toes were present in the foot, the animal's weight was now principally borne by the middle digit. In the upper Oligocene *Miohippus* had definitely evolved from and replaced *Mesohippus*; it had three toes and three fingers in hind and fore limbs respectively. You can see in the diagram a little splinter of bone still clinging to the top of the outer or fourth finger, all that remains of the disappearing fifth digit. This animal, which, like its ancestors, dwelt in N. America, was slightly larger than its predecessor. It soon gave rise to four lines of descendants: (1) *Anchitherium*, which closely resembled *Miohippus*, wandered across to Asia and Europe, but became extinct in the middle Miocene; (2) *Parahippus*, also very similar to its ancestor, migrated to S. America, where in early Miocene times it, too, became extinct; (3) *Hypohippus* wandered, in the beginning of the Miocene, to S. America, eking out an existence there until the middle of that period, when it suddenly vanished. This Forest horse possessed three toes in the foot and three fingers in the "hand," but vestiges in the shape of small nodules of bone, of the thumb and little finger persisted. *H. equinus* stood 40 inches high, while the Nebraskan *H. matthewi* was even taller. (4) The

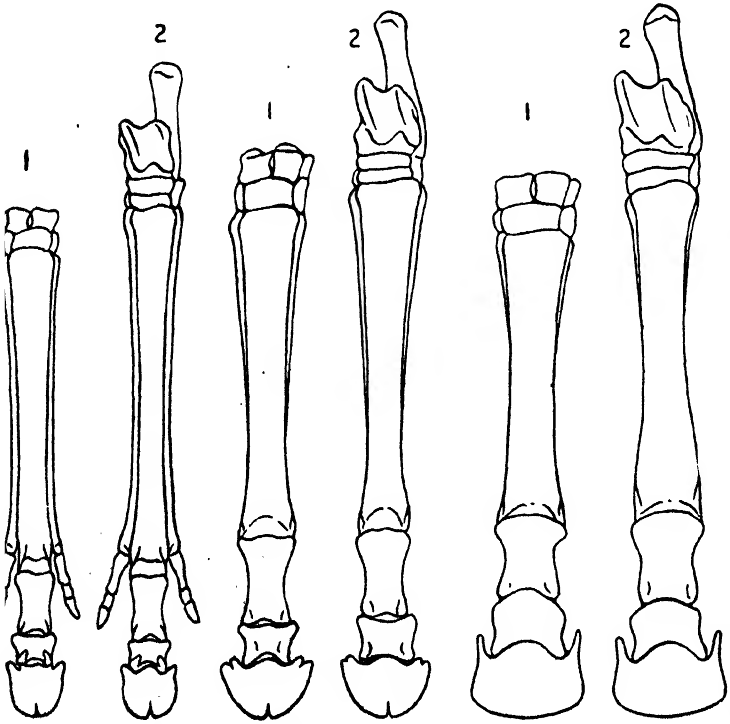
FIGS. 11, 12.—Seven Pairs of Horses' Feet.
(1 Fore Foot. 2 Hind Foot.)
For other illustrations, etc., of the horse and its ancestors see Figs. 13, 14, 15, 72, 78, 164, 166, 167, 168.



fourth line of descent, in the direct line towards modern horses, was represented in the middle Miocene by *Merychippus*.

*Merychippus* was three-digited in all limbs, though remnants of the fifth finger occasionally persisted. While *structurally* three-digited, *functionally* it was one-digited, as the side digits failed to reach the ground. From *Merychippus* arose, in the late Miocene, *Protohippus*, another three-digited horse.

From this latter sprang three branches: (1) *Hipparion*, which spread north to the Behring bridge and thence to Asia and Europe, where it became extinct in the mid Pliocene. There were many varieties of this creature: *H. whitneyi*, the Desert horse, kept to N. America and stood 40 inches high, while *H. gracilis*, standing 44 inches in height, got as far as Greece! (2) *Hippidion* was the S. American transmutation of *Protohippus*. It flourished throughout the Pliocene, and only became extinct in the lower Pleistocene as a form called *Onohippidion*. Its mean stature was 49 inches, and it carried short, stout, one-toed feet and one-fingered "hands," both limbs bearing, on each side of the now huge third or middle digit, remains of the second and fourth ones. This *Hippidion* branch is of great interest in that it embodies the first one-fingered horse in S. America. How near *Onohippidion* was to gaining entrance into recent geological days is shown by the fact that its hoofs have been unearthed in




Protohippus (*Hipparion*): Lower Pliocene — Pliohippus: Pliocene — Equus: Recent or Quaternary Rocks

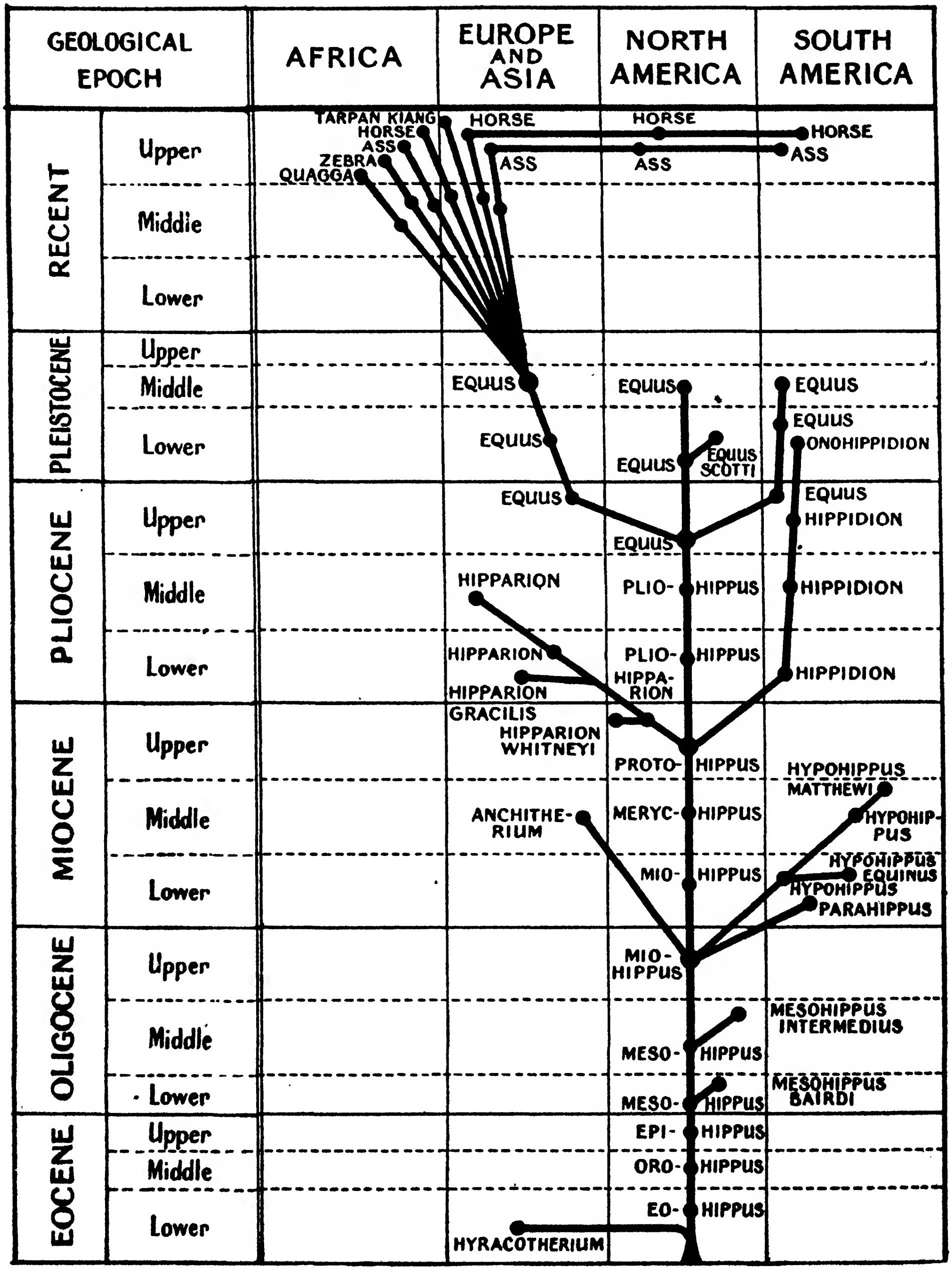



FIG. 13.—Evolution of the Horse and of its Relations and Ancestors. (After *Lull*.)

Patagonian caves with the horny material in a fairly fresh state of preservation. (3) *Pliohippus*, in the direct line of descent, remained in N. America throughout the Pliocene, becoming, towards the end of that period, the first *Equus* or true horse with one-fingered fore and hind limbs. Remains of the second and fourth digits are still attached, as splint-bones, to the long and sturdy middle digit or " cannon-bone."

This upper Pliocene N. American horse quickly gave rise to three branches: (1) One which went into the southern continent only to become extinct in the mid Pleistocene; (2) another that remained in N. America, but also went the way of all flesh. Thus we have the remarkable state of affairs of an animal, after a long and laborious evolution in America, suddenly becoming extinct in the land of its birth while surviving in foreign parts. The cause of the extermination was probably some deadly parasite-inoculating insect similar to the tsetse fly of modern equatorial Africa.

(3) The representatives of the third and successful branch of horse-ancestors went north and crossed over into Asia and Europe via the then Behring isthmus, in which countries they flourished throughout the Pleistocene and into modern times.

In the mid and upper Pleistocene the *Equus* of the Pliocene had broken up into several branches. One of these migrated to Africa, and by further subdivision gave rise to the African horse, ass, zebra, and quagga, the last of which only quite recently became extinct. Another branch remained in Eurasia and developed into the ass, tarpan, kiang (the only living wild equines) of the Gobi desert, and the modern horse, an animal standing 8½ hands or 34 inches (Shetland pony), to 18¼ hands or 73 inches (draught-horse). The last step in this wonderful equine drama took place when a relatively few years ago the Spanish Conquistadores imported a few horses into America. Some of these strayed from the settlements, ran wild, or became *feral* as it is termed, and spread rapidly until vast herds overran both continents, thudding their one-digited limbs over the fossils of their five-fingered ancestors. Such is the marvellous pedigree of man's most useful companion (Fig. 13).

Probably all horses are descended from an animal about the size of a rabbit. In the Table of the Earth's Strata, on page 57, you will see the various layers in which all these fossil feet of the horse have been found.

We are so accustomed to the big hoof of the horse that we are apt to forget that this hoof is only the large overgrown nail of the middle digit—finger- or toe-nail as the case may be. (See Figs. 11, 12.) In several recent cases horses have had divided hoofs, as you see on page 12.


FIG. 14.—Horse with all its hoofs divided. A " throw-back " to an ancestral stage. INSET : Digits IV, III (the normal " hoof "), and II (a splint-bone buried in the flesh covering the cannon or shank).

These instances, together with the fact, to be considered later, that the foal, before its birth, has three toes, are further proofs that the horse has evolved from an ancestor which had, and moved about on, more than one toe.

More light is thrown on its ancestry when we consider the order of animals to which the horse belongs. All hoofed animals are put together in one order, and are called *Ungulates* (this word comes from the Latin *unguis*, a finger-nail). Among Ungulates there are some remarkable forms, but the *Equus* genus, containing horse, zebra, ass, etc., are the only animals that walk on *one* toe. One of the oldest of the order is the tapir, found in America, and shown in Fig. 16. This order also contains the horse with one digit, the camel and giraffe with two, the rhinoceros with three, the pig and hippopotamus with four, the hyrax with four fingers and three toes, and the elephant with five digits.

To realize that these large hoofed animals have come from smaller ancestors, you should study well the hyrax in Fig. 17. At the Cape they call it the dasee, and it is a common object on rocky hill-sides, emitting its plaintive cry and working its jaws about *as though it were chewing the cud.* It was, no doubt, this curious habit that led to the Scriptural description of these creatures as an " exceeding wise " though " feeble

folk" that "chew the cud but divide not the hoof."[1] That the little beast is "wise" may be true, for it is almost impossible to stalk or trap it, and its foot is not divided; but it does not chew the cud. Many people think it is a sort of rabbit, and no wonder; but the skeleton, as well as other structures, shows it is not.

This little animal looks rather like an overgrown rat, or perhaps reminds you of a guinea pig; but it is of amazing interest. For hundreds of thousands of years it has remained almost unchanged. It is the nearest living representative of the primitive ancestor of the elephant, the horse, the cow, and even the woolly mastodon. There are fourteen species of this animal still living. It is literally a walking museum; and perhaps only two *living* animals (the duck-mole and the sphenodon) are of equal interest.

Though its skeleton shows clearly the points of the hoofed-animal class, some of its teeth are like those of a rhinoceros, and others like those of a rabbit or rat; and between these two extremes of teeth are some intermediate forms. The intestines of this animal tell a most ancient story, for it has paired cæca—*i.e.*, two blind guts—and in this structure it resembles birds. When we remember that mammals diverged from

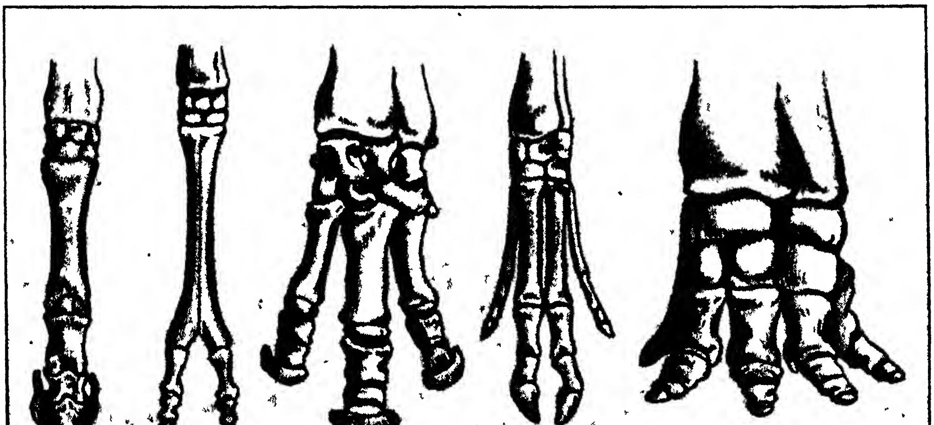


FIG. 15.—Feet of Ungulates, showing Bones. Horse, Camel, Rhinoceros, Pig, Elephant.

The horse has discarded four of its ancestral digits in order to perfect a limb for speed over hard, dry ground The elephant, on the other hand, whose chief habitat is the softer ground of the jungle, has retained its five digits because it is advantageous to a creature of this great bulk to distribute its weight over as wide an area as possible. As will be seen, the camel, rhinoceros and pig occupy intermediate positions between the horse and elephant.

[1] Psalms 104, 18; Proverbs 30, 24–26.

FIG. 16.—A Tapir.

One of the ungulate or hoofed mammals. Four species exist in Central and S. America, and a fifth in Malacca and Borneo. It has four digits in the front, and three in the hind feet. The teats are in the groin.

reptiles before birds did likewise, it will be seen that this structure, common to birds and dasees, carries us back into a very ancient period.

When any animal has points in common with many other animals of distinct groups it is called a generalized form. The coney is a fine example of a generalized form, and it is most important that we should learn exactly what is meant by this term; for a generalized form gives rise to many varieties, and may be said to be the parent from which different species spring.

FIG. 17.—The Hyrax, Dasee, or Coney.

An ungulate or hoofed mammal of Syria, Arabia, and Africa, with affinities to elephants and rhinoceroses. It is a wonderful rock-climber. In the fore foot the thumb is rudimentary; in the hind foot the great toe is absent, and the fifth toe rudimentary.

Generalized forms also usually become extinct, for they cannot hold their own in life's struggle. In this world it is sometimes the specialist that succeeds. The horse is a highly specialized form.

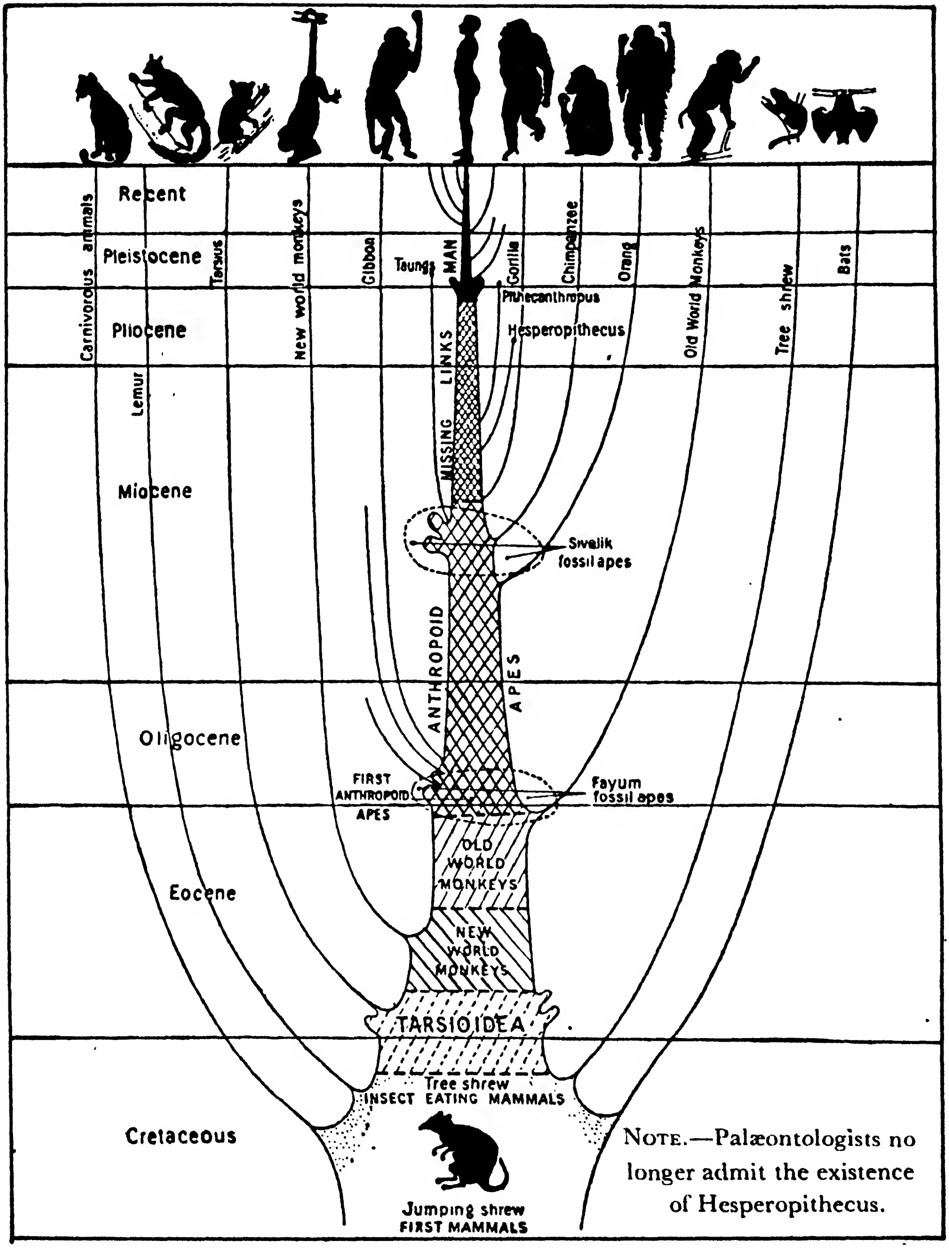



FIG. 18.—Man's Family Tree.
(Modified from Dorothy Davison's *Our Prehistoric Ancestors.*)

Now let us pause and see at what stage we have arrived.

*First*, we have seen, from considering the acorn, that a small thing which a mouse can carry becomes, in the course of 200 to 400 years, so large as to shelter scores of people from the sun. All it needs is time to grow.

*Second*, we learnt from the bicycle that we get simple, imperfect forms first. We learnt the same thing in the development of the horse's foot. It began in the small animal with the generalized form, having five toes; but by specializing for thousands and thousands of years it threw off all but the middle toe, and became that most highly developed animal, the horse, with one very large toe.

*Third*, we learnt also from the ancestors of the horse that small animals of a generalized form can give rise to many different kinds of large animals in the course of ages. Nothing can be plainer and nothing can be more wonderful than that the horse, elephant, camel, man, and many others, have sprung from a group of very small animals, not unlike existing members of the *Soricidæ*, or Shrews (pages 15, 126, 127).

*Fourth*, we saw, in the case of the rifle and the piano, which have both come from the old bow and arrow, that two most unlike things developing along different and diverging lines have yet evolved from a common source.

Now, these examples and these laws are noted merely to put us in the right attitude to consider a few of the millions of living things, and to observe the grandeur of an evolution which has required millions of years.

## CHAPTER TWO: ASTRONOMY

MOST people have seen the stars on a clear night, but very few take the trouble to inquire what they are or what we know of them. Wise men studied them thousands of years before Evolution was discovered; and, though they are so many billions of miles away, we know a great deal about their history, nature, forms, and distances. Perhaps in no other department has man done so much as in astronomy.

The word " astronomy " is from two Greek words—*astron*, star, and *nomos*, law, and so the word means classing or arranging the stars. The Latin word for " star " is *stella*, so when we speak of the system of the stars we call it the stellar system.

As planets and satellites move round nearly in a circle, the path through which each body travels is called its orbit, which is from the Latin *orbis*, a circle. When a small body revolves round a larger it is called its satellite, from the Latin *satelles*, an attendant; thus the moon is the earth's satellite.

The Latin word for " sun " is *sol*; so when we speak of the sun and all the bodies which revolve round him we call it the solar system.

There has been a regrettable tendency of late, even among eminent astronomers, to speak of " universes " in the plural and to separate what is called " our universe " from " distant universes." By the very implication of the word the universe includes our world and all the other worlds and bodies in space; it is from the Latin *universum*, the whole; and this Latin word is made up of two Latin words—*unus*, one, and *verto*, to turn. It is a most suitable word; it means all the worlds and bodies, and, as they are always going round, we may say they turn—the turning whole.

Now we want to learn how the stars and our world all came into their present state. Were they made just as they are, or do they change? Are some young and some old? In a word, have they evolved from some other form of matter, and are they still evolving?

Before we can look for laws and their lessons we must refresh our memories by an outline of the facts of that part of the universe which is best known to us. In other words, we must try to be clear about the solar system. The solar system includes the sun, with those planets, satellites, and smaller bodies which revolve round the sun. The stellar

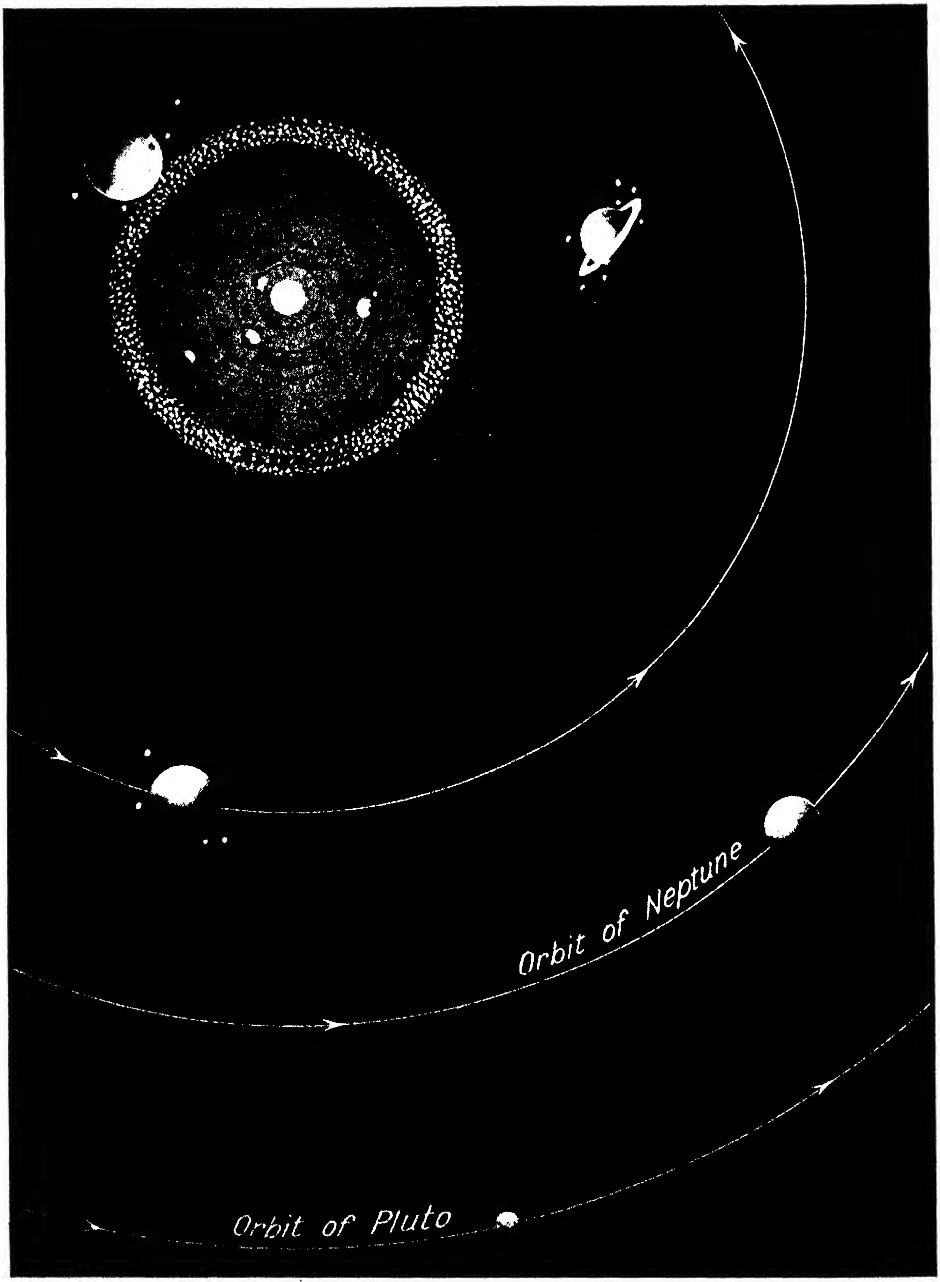



Fig. 19.—Paths of the Outer Planets of the Solar System.

system includes the solar system and all the stars and other bodies which can be seen and discovered by man. Our solar system is only a small speck in the great stellar system.

For the sake of clearness we will deal with the smaller first.

Fig. 19 tells its own story. In the centre of all, a bright body represents the sun. The circles show the orbits, or paths, in which the planets revolve. Their sizes are various; the distances enormous. It seems to us a measureless space; it is, in reality, a small compartment in the infinite world of stars.

Note the distance of the earth, which is the third body from the sun. It seems quite near the sun, but it is nearly ninety-three million miles away. If this conveys any meaning, you may try to form some idea of the distance of the farther planets.

There are nine principal planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and the newly discovered Pluto. I have given them in the order of their distance from the sun, Mercury being the nearest and Pluto the farthest.

In early days most of the bright bodies in the heavens were supposed not to move, and they were called fixed stars; though, as a matter of fact, there are no fixed stars, for all the stars are suns and they all move.

But the sun and moon and a few bright bodies were clearly seen to move, and the Greeks called these moving bodies planets, which means the wanderers. They enumerated seven: the Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn; and this is why we have seven days in the week. These days, some of which still retain their planetary names, as Sun's day, Moon's day, Saturn's day, were treated with great reverence and included in various religious systems. Now, however, we regard the sun as a central governing body, the moon as a satellite of the earth, and Pluto, Neptune, Uranus, Saturn, Jupiter, Mars, Earth, Venus, and Mercury, as the nine planets of the solar system.

Note the smallness of the earth (Fig. 20) when compared with the larger planets, which we shall describe more fully. Their distances from

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FIG. 19 (*Left*).—Paths of the Outer Planets of the Solar System.

Strictly they are ellipses, but reduced to this scale they appear as circles. The lengths of the paths in miles from without inwards are: P., $2{\cdot}17 \times 10^{10}$; N., $1{\cdot}67 \times 10^{10}$; U., $1{\cdot}07 \times 10^{10}$; S., $5{\cdot}21 \times 10^{9}$; J., $2{\cdot}89 \times 10^{9}$; Ast.*, $1{\cdot}86 \times 10^{9}$. Their distances from the sun are (in miles) Ast., $3{\cdot}12 \times 10^{8}$; J., $4{\cdot}83 \times 10^{8}$; S., $8{\cdot}85 \times 10^{8}$; U., $1{\cdot}78 \times 10^{9}$; N., $2{\cdot}79 \times 10^{9}$; P., $3{\cdot}8 \times 10^{9}$. For Inner Planets see Fig. 21.

* Ast. = Asteriods or Planetoids.

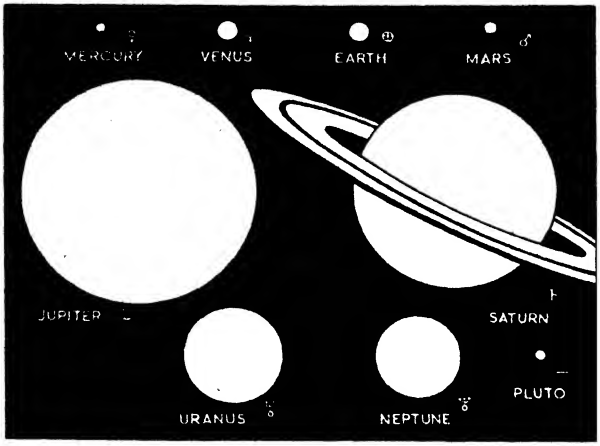



FIG. 20.—The Comparative Sizes of the Planets.

Reading from left to right downwards, the planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Their diameters in miles, from innermost to outermost planets, are as follows: M., 3,194; V., 7,842; E., 7,927; M., 4,263; J., 89,230; S., 74,938; U., 33,180; N., 30,880; P., 7,842 (?). See also Figs. 21–23, 26–31.

the sun have been carefully calculated; but, as mere figures convey so little in the gigantic measurements of astronomy, we must show the facts by other means. The path in which a planet moves round the sun is called its "orbit," and Fig. 21 gives a correct idea of the distances. The bright, small body almost in the centre represents the sun. The smallest circle is the path of *Mercury*; the next the path of *Venus*; the third circle the path of the *Earth*; the greatest the path of *Mars*.

Between Mars and Jupiter is a wide gap, in which we should naturally look for another planet. In this gap, up to 1931, there had already been discovered 2,000 little bodies, called "asteroids," which probably represent a single planet that has burst into fragments. Most of these asteroids or planetoids are small, few of them being larger than, say, motor-buses. Two fresh ones were discovered early in 1931: *Ba* by Professor Lacchini, and *Ca* by Count Volta (great-great-grandson of the famous electrician who discovered the "voltaic" pile and thereby gave us the word "volt"). Both observers discovered the planetoids while working in the Pino Torinese Observatory. Five at least of the planetoids have known diameters: *Ceres*, 477 miles, *Pallas*, 304, *Vesta*, 239, *Juno*, 120, and *Eros* with a mean diameter of only 18½ miles. In 1931 this planetoid was found to be sausage-shaped and turning about a short axis—hence the variability of its light; its long axis is 29, and its short 8, miles. While *Hector* is the outermost of the planetoids, and therefore the farthest from the sun and ourselves, with a year equal to 12·1 of our years, *Eros* is the innermost and consequently the nearest to us and to the sun. Its year is equal to 1·76 of ours, or 643 days. The last close opposition

of *Eros* was in 1894. In 1931 it was again close to the earth and was then very carefully observed by astronomers with a view to checking all the measurements of the solar system (and from them stellar measurements) in Earth–Eros terms.

The white disc in the centre of Fig. 19 represents the sun, and a small circle marks the path of Mars, between which and the sun are shown the orbits of the inner planets Mercury, Venus, and Earth. Next to Mars' orbit, and outside it, is a ring of dots representing the asteroids; then comes a circle, the path of Jupiter; and beyond this the circles represent, in order, the paths of Saturn, Uranus, Neptune, and Pluto.

It is difficult to realize the vast distances concerned. As we have seen, the earth appears comparatively quite near the sun, and yet it is nearly 93 million miles from it. Various attempts have been made to bring this distance home to us. A bullet travelling at 2,500 ft. per sec.—that is, about 1,704 miles per hr.—would require six years and 73 days to reach the sun; yet light makes the journey in less than eight and a half minutes. Now, if you begin to grasp the distance of the earth from the sun, remember that the distance from Pluto to the sun is nearly forty times greater!

The planets of our solar system are all, more or less, *dark* bodies, borrowing their light from the sun; they all rotate on their own axes; they revolve round the sun; and revolving around them are smaller bodies, called satellites, which

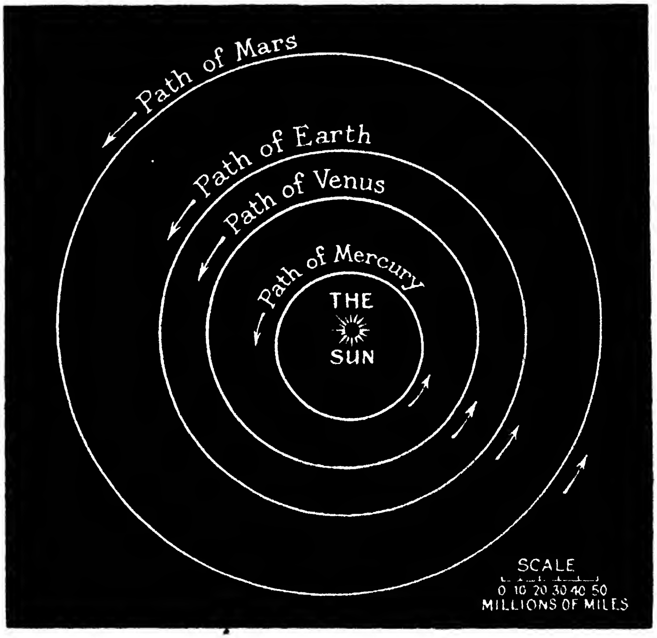



FIG. 21.—Paths of the Inner Planets of the Solar System.

They are really ellipses, though shown here as circles. The lengths of the paths in miles from without inwards are: M., $8{\cdot}48 \times 10^8$; E., $5{\cdot}58 \times 10^8$; V., $3{\cdot}72 \times 10^8$; Mer., $2{\cdot}16 \times 10^8$. Their distances from the Sun are: M., $1{\cdot}41 \times 10^8$; E., $9{\cdot}28 \times 10^7$; V., $6{\cdot}71 \times 10^7$; Mer., $3{\cdot}59 \times 10^7$. For Outer Planets, see Fig. 19.

*From the original drawing by Ellison Hawks, F.R.A.S.*

FIG. 22.—The Planet Jupiter, showing his belts and one of his eleven Satellites.

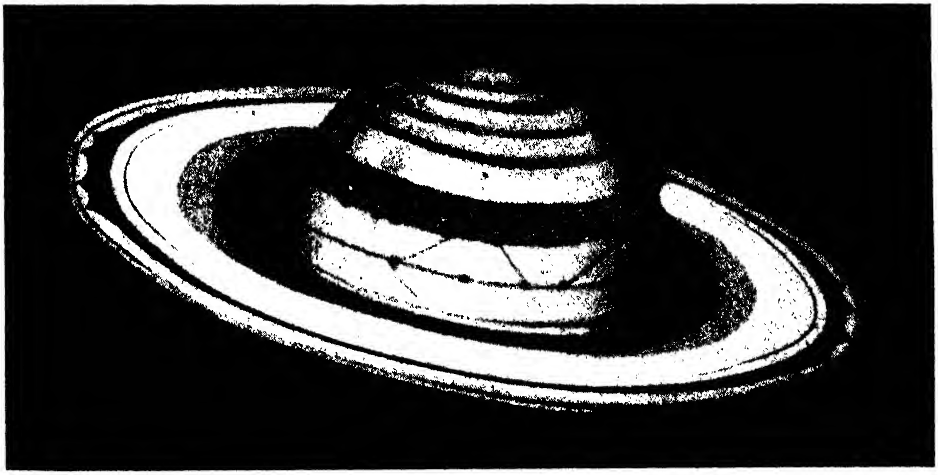
It is the largest of the planets and is surrounded by an atmosphere of marsh-gas ($CH_4$)and ammonia 5,000–6,000 miles thick overlying a thick surface of ice. The period of rotation (9 h. 55 m.) is very short and is the cause of the great equatorial bulge, the diameter at the equator being 5,000 miles greater than that between the poles. The speed of rotation at the equator is 41,120 ft. per sec. as compared with 1,462 ft. per sec. for the earth. On the other hand, where gravitation is 32·2 ft. per sec. on earth, on Jupiter it is 85 ft. per sec.

also rotate on their own axes. Jupiter is the giant planet (Fig. 22). Its equatorial diameter is 88,500 miles — a little over eleven times that of the earth. In *volume* it is over a thousand times greater, but in *density* it is one-fourth that of our planet. Its surface is 122 times that of the earth, and its distance from the sun is a little over 483 million miles. The huge planet is crossed by numerous lines—the famous belts—parallel to its equator. From its low density it used to be regarded as a semi-sun, a hot liquid or gaseous ball producing its own heat by processes similar to those going on in the sun itself. It has a very extensive atmosphere of clouds and vapour whose reddish hue was attributed to the transmission and reflection of light from the glowing red surface below; a view less acceptable to-day owing to recent discoveries.

Many factors have to be considered in any estimate of the internal and surface temperatures of a planet. All the bodies of the solar system being offspring, so to speak, of a common parent, they may be assumed to have started on their individual careers with the same quantity of

heat, mass for mass. Just as a big iron casting takes a week or so to cool, while a very small one takes but a few minutes, so the bulkier bodies of the solar system conserve their heat more effectively than the smaller ones. Again, some of the planets were born far away from the centre of the sun, some relatively close to it, others at intermediate situations between the two extremes. Mercury, close to the sun, is to all intents and purposes roasted; while Pluto, about the same size, shivers on the confines of the system, where the thermometer would stand at 480 degrees of frost. This distance-of-planet-from-sun factor led the late Sir James Jeans to the opinion that the outer planets must be colder than anything we ever experience on earth and that " even Jupiter . . . must be about 270 degrees below zero on the Fahrenheit scale. . . . The clouds of Jupiter must presumably be clouds of carbon dioxide, or of some other gas which only condenses at very low temperatures." In any case it is obvious the planet is not fitted to be an abode for life. Finally, we must not omit to mention that this giant among the planets is attended by eleven moons.

Saturn (Fig. 23) is the show planet of our system. It is unique in that it not only has nine moons, but is surrounded by a series of " rings " such as has been found nowhere else in the universe. Its mean distance



*From the original drawing by Ellison Hawks, F.R.A.S.*

FIG. 23.—The Planet Saturn and his Rings.

It has nine satellites, and is the second largest planet. It is even more flattened than Jupiter, the equatorial diameter being 8,000 miles greater than the polar. Saturn has a remarkably low density, and its atmosphere consists of marsh-gas ($CH_4$) and ammonia ($NH_3$) overlying a thick surface of ice. The rings are probably a broken-up former satellite and are about 50 miles thick and 82,000 miles wide.

from the sun is 886 million miles, and its greatest distance from the earth over 1,000 million miles. It is even farther removed from solidification and adaptability for bearing life than is Jupiter. The most remarkable peculiarity of Saturn is the system of rings, first discovered by Galilei, though their true nature remained unknown for nearly fifty years, till Huyghens, in 1655, explained them. But it was not until another twenty years that the apparently single ring was resolved into two with a dark zone separating them, and in 1850, both here and in America, a third ring was discovered. These rings, the brightest of which is about 17,000 miles broad, are not continuous sheets of incandescent matter, but swarms of moonlets each circulating around the mother planet in approximately the same plane. "There is every reason for thinking," says Sir James Jeans, "that these tiny moons are the fragments of a body which at one time formed a quite ordinary full-sized moon of Saturn. This probably entered the danger-zone of Saturn . . . and paid the usual penalty of being shattered into fragments." Just as in the remote past a passing star tore out a part of our sun and thus formed the planets; just as the sun tore out portions of Jupiter and Saturn and formed their moons; so "Saturn itself broke up its nearest satellite into millions of fragments and so formed its own system of rings." For every smaller body of a plastic nature revolving around a larger one there is a danger zone, to enter which spells disaster for the smaller body. Saturn's innermost satellite is only just outside this danger zone. Shortly, possibly before the extinction of life on earth, its orbit will have contracted sufficiently for it to enter the zone; then it will burst and its fragments form yet another ring. A similar, though not quite so imminent, fate awaits Jupiter's innermost satellite. "In the same way," says Jeans, "although in the very far future, our own moon must inevitably be drawn in closer and closer to the earth, until finally it approaches too near for safety and meets the same fate. After this the earth will have no moon, but will be surrounded by a frill of rings like Saturn." Thus does the sword of Damocles hang over the innermost satellite of a planet.

We must now call attention to the most extraordinary behaviour of the outermost satellites of certain planets. The only known moon of Neptune, the outermost one of Saturn, and the two farthest ones of Jupiter, do not revolve, like normal satellites, round and round the equator of the parent planet, but in a plane more or less at right angles to the equatorial plane; that is, they revolve in a meridional plane passing through the planet's two polar regions. The most plausible explanation of this exceedingly irregular conduct is that these particular satellites were

not born of the planet to which they are attached. They are really foster children that have been annexed. It is supposed that the powerful pull of these massive planets detached certain of the larger asteroids from their orbits and compelled them thereafter to move in a new orbit about the planet.

Uranus, just visible to the naked eye, has a diameter of 33,180 miles and is 1,782 million miles from the sun. It has four moons.

We must refer to Neptune in more detail, because its discovery is one of the greatest triumphs of mathematical astronomy since the time of Newton. It was noticed that Uranus did not move in the orbit in which, according to all calculations, it ought to have moved. The mathematicians concluded, therefore, that there must be some other planet which drew it away from its proper path. So accurate were their calculations that they were able to tell the astronomers exactly where to search for another planet; and in that very spot Neptune was discovered on the night of September 23, 1846, by the Observatory at Berlin. Leverrier, a Frenchman, and Adams, an Englishman, both separately made this discovery by mathematics. The mean distance of Neptune from the sun is 2,800 million miles. It completes a revolution about the sun in 164·8 of our years; its diameter is 30,880 miles; and it has one moon.

Up to the beginning of 1930 Neptune was the outermost known planet of our solar system. About 1915 Dr. Percival Lowell predicted the presence of yet another body moving in an orbit outside that of Neptune. His prediction was verified in 1930 by Mr. C. Tombaugh of the Arizona Observatory. *Pluto*, as the new planet has been called, has a more elliptical orbit (eccentricity, 0·25) than any other planet; so much so that at perihelion (*i.e.*, when nearest the sun) it actually cuts across the path of Neptune. The mean distance of Pluto beyond Neptune is 1,000 million miles, which would give it a distance of 3,800 million miles from the sun. The new planet has about $\frac{1}{1000}$th of the brightness of Neptune. Heavenly bodies are classified, according to their brightness as seen from earth, in divisions called "magnitudes," which, however, bear no reference to size. The brightest stars are called "first magnitude"; those just visible to the naked eye, "sixth magnitude" stars; and so on. On a photographic plate, after an hour's exposure, a "fifteenth magnitude" planet, such as Pluto, leaves a tiny streak—due to the planet's motion; whereas a star, being "fixed," leaves a round image. Thus the known diameter of our solar system has been increased, through the discovery of Pluto, to 7,600 million miles.

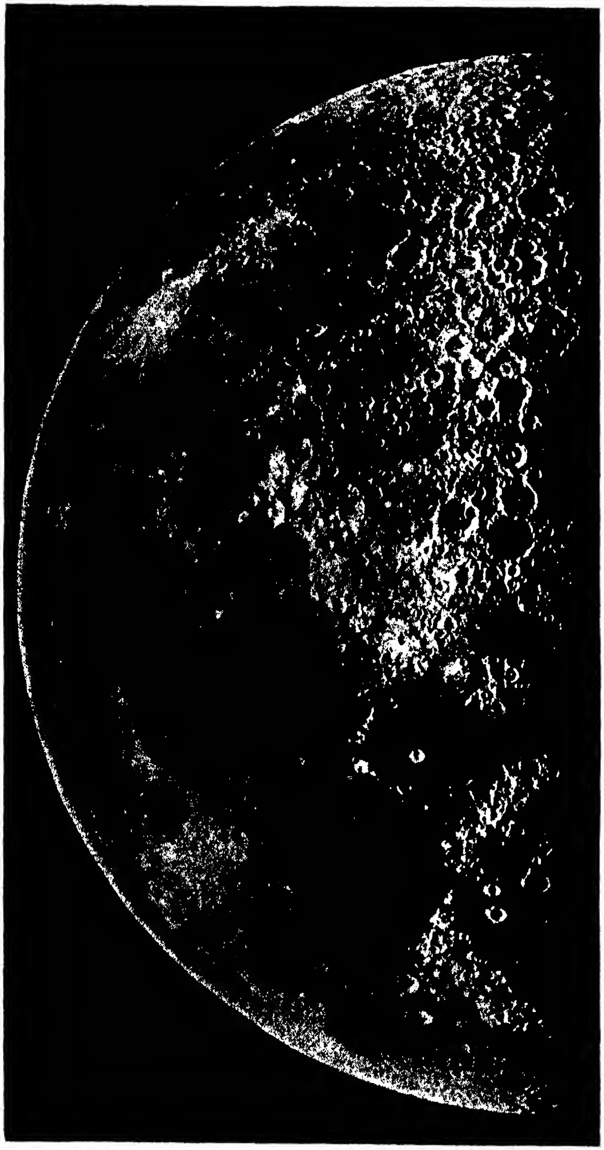


FIG. 24.—The Moon at First Quarter.

The moon is the only satellite of the earth, around which it revolves at a distance of 237,000 mi., covering 149 million mi. in 27·3 days at a speed of 3,379 ft. per sec. Its diameter is 2,160 mi., its weight $7{\cdot}2 \times 10^{19}$ tons or 100/8,156 that of our earth, and its density 3·33 (earth 5·52). The equatorial velocity is only 12·28 ft. per sec. as compared with 1,462·0 ft. per sec. for the earth, while gravity on the moon is 5·47 ft./sec.$^2$ as compared with 32·2 ft./sec.$^2$ on earth. A pound weight on earth would weigh 2·4 oz. on the moon. For these reasons the moon has lost all its water and air. The moon is the principal cause of our tides, the sun being a secondary cause. When the pull of the sun and moon coincide in direction, tides are exceptionally high. Many million years ago the moon probably formed an integral part of the earth.

An illustration may help towards a conception of the dimensions of the space in which the members of our own solar family are poised. Let a globe two feet in diameter represent the sun. A mustard seed 132 feet away would then stand for the innermost planet, Mercury;

a pea 142 feet distant would represent Venus, and another, 215 feet away, our earth. A hemp seed at 327 feet would stand for Mars; several grains of sand sprinkled around the 550 point would represent the asteroids, while a tennis-ball a quarter of a mile off and a billiard-ball 700 yards away would stand respectively for Jupiter and Saturn. Finally, a cherry half a mile, a small walnut a mile and a quarter, and a pea two miles distant from the two-foot globe, would represent respectively the positions and sizes of the outermost planets, Uranus, Neptune, and Pluto. If, now, you were to put an orange 8,000 miles off, on the opposite side of the earth, it would represent the nearest star to our sun!

The moon is a dead and airless world whose surface is covered with extinct volcanoes, as the wonderful photograph given here (Fig. 24) shows. It has had its birth, childhood, and maturity, suffered the decay of old age, and has finally died. In these respects it differs entirely from Jupiter and Neptune, which are still in their fiery, active youth. Strange thoughts arise when one contemplates the solar system as a family, in which some are young, some in the prime of life, some aged and worn out.

Our solar system is an island surrounded by a stupendous engirdling void, in which the nearest known neighbour system is at a distance quite inexpressible by earthly numbers. In order to indicate how far away it is, we must express the distance in one or other of the units of measurement made use of in astronomy: (1) the earth-sun distance, 93 million miles; (2) the *siriometer*, a million earth-sun distances; (3) the distance covered by a ray of light, travelling at 186,000 miles a second, in one year; this is the "light-year" or 6,000,000,000,000 miles; (4) the *parsec*, 3¼ light-years, or about 20,000,000,000,000 miles. The nearest star to us, *Proxima Centauri*—a faint member of the *Alpha Centauri* group—is 4·1 light-years distant.

The number of stars which can be seen by the naked eye (including cases where a binary—two stars revolving round a common centre—is seen as one) is about ten thousand. But the camera-telescope "sees" and records stars so distant that no human eye, even though aided by the most powerful lenses, can see them. The number of *recorded* stars must be well over 300,000 million. According to Sir James Jeans the stars in *our* system alone "may well be of the order of 400,000 million." About two million extra-galactic (*i.e.*, beyond the Milky Way) nebulæ are visible in the 100-inch telescope, and each of these holds, on the average, 300,000 stars, so that there must be at least 600,000 million stars within the range covered by the 100-inch telescope. Again, the number of dark bodies

FIG. 25.—Laplace. Born 1749; died 1827.

(obviously outside any numerical reckoning) may (Arrhenius thinks they certainly do) exceed the luminous ones. Beyond these extra-galactic systems, out and ever out in the depths of unplumbed space, the law of continuity indicates that "universe must follow universe in procession up to infinity." This latter view, no doubt, conflicts with that held by certain relativist astronomers who claim that the universe has a definite finite boundary, but their claim is based principally, not on direct observation, but on higher mathematics.

When we remember that the stars are suns, just as our sun is a star, and that each star probably has its own system of planets, though they are too small to be seen at such an immense distance, we begin to feel dazed by their infinite numbers and distances. We turn, therefore, with enthusiastic curiosity to inquire how this system of bewildering marvels has arisen; if it bears any marks of growth or of decay, of its origin or of its end. Were the heavenly bodies made once for all as they are now, or have they been evolved by the same laws which have produced the protozoa of the ocean and the geniuses of mankind?

Until the last few years the *nebular hypothesis* was generally accepted by astronomers as accounting for the gathering together into one orderly system of our sun, planets, and satellites. To-day, however, so far as our solar system is concerned, it has been abandoned in favour of the *tidal-disruption hypothesis*, although as explanatory of the origin of certain star systems the nebular hypothesis is still as firmly established as when it was formulated by Kant, Laplace, and William Herschel.

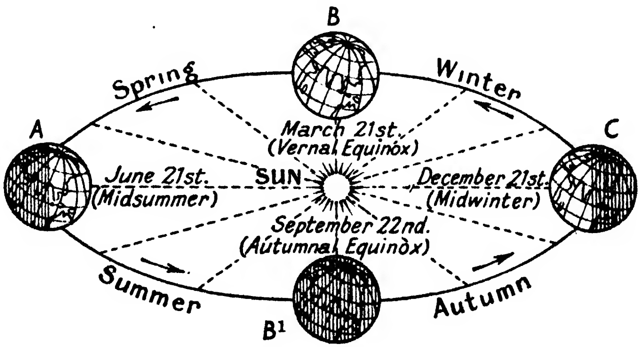



FIG. 26.—The Earth's Orbit or Path round the Sun.

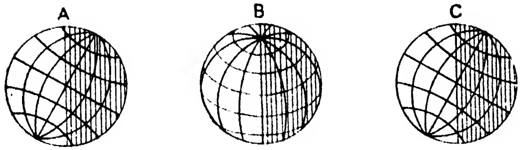



FIG. 27.—Different Inclinations of the Earth to the Sun.

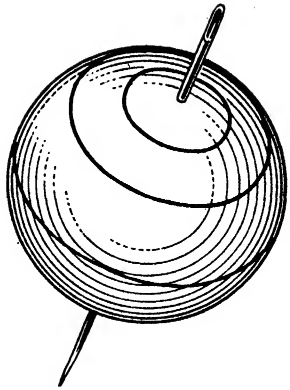


FIG. 28.—The Earth turning upon its Axis.

Kant spent his life as professor at the University of Königsberg. In 1755 he first announced that all the bodies composing the solar system originated from a vast contracting nebula. Afterwards he abandoned scientific speculation and achieved immortality as a metaphysical philosopher. Laplace was the son of a farmer, but through the influence of D'Alembert he obtained the post of Professor of Mathematics in Paris. In 1796 he advanced the famous nebular theory, based entirely on mathematics. The hypothesis has become especially associated with his name because he went into great detail and presented convincing mathematical evidence in its support. Herschel came to England from Hanover at the age of nineteen, and settled at Bath as organist and music teacher. His hobby was making telescopes and studying the heavens at night. On March 13, 1781, he discovered the planet Uranus, which at once made him famous. He gave up music, constructed better telescopes, and settled at Slough, where for forty years, aided by his illustrious sister Caroline, he was engaged in solving some of the mysteries of the universe. His constant labours soon revealed the fact that between those diffused wisps of luminous, cloud-like matter that characterize a nebula and an object hardly distinguishable from a star with a slight haze round it, *every intermediate grade* could be found. In this way he was led to the splendid theory of the gradual transformation of nebulæ into stars.

FIG. 29.—The Relative Sizes of the Earth and the Moon. (See also Fig. 30.)

Whatever views we of to-day may hold with regard to the nebular hypothesis, all must agree

that it has a most marvellous history. Kant by abstract speculation, Laplace by mathematical calculation, Herschel by direct observation, independently came to the same conclusion—that the whole visible universe has evolved, and that the stars, suns, planets, and other bodies within it have attained their present form by condensation from a vastly attenuated and diffused gas. This is the great nebular hypothesis. Though *nebula* is the Latin for a mist or cloud, we must not think of the nebula from which stars have come as like the mist or cloud of our atmosphere, but rather as composed of much lighter gases than any with which we are familiar. Hypothesis (Greek: *hypo*, under, and *tithenai*, to place) means a scientific "supposition" to explain observed facts. That stars, suns, and planets were formed from some primal mist is the explanation offered by the nebular hypothesis. In formulating this hypothesis the three illustrious men we have named naturally differed in points of detail, but in the main they all agreed. Kant first gave the theory to the world in 1755. Since then hundreds of men have devoted their lives to astronomy and thousands of discoveries have been made; and we have now to inquire whether, after all these years of remarkable scientific activity, the evolution of the millions of worlds is proved or discredited.

We will glance at the history of the earth and the sun. The earth's

Fig. 30.—The Birth of the Moon.

The more or less plastic spherical earth rotates faster and faster; this causes it to change its form to an ellipsoid or compressed sphere (egg-shaped). Next it becomes somewhat pear-shaped, after which a mass of its interior parts company from the stalk of the pear to form the new-born moon. The latter now recedes from its parent, which gradually returns to a spherical (oblate spheroid) shape.

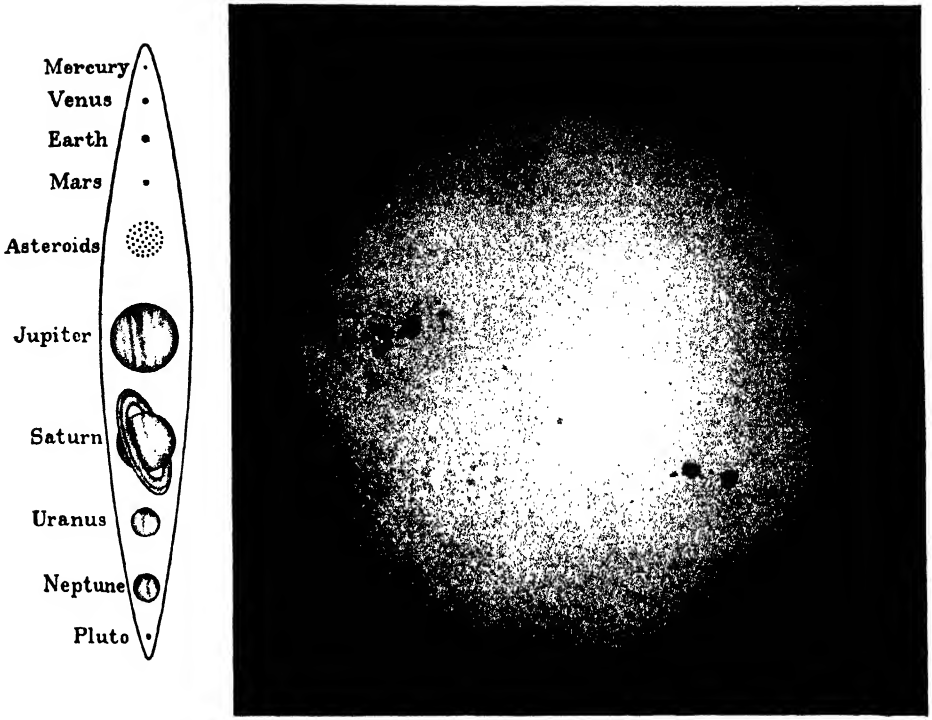


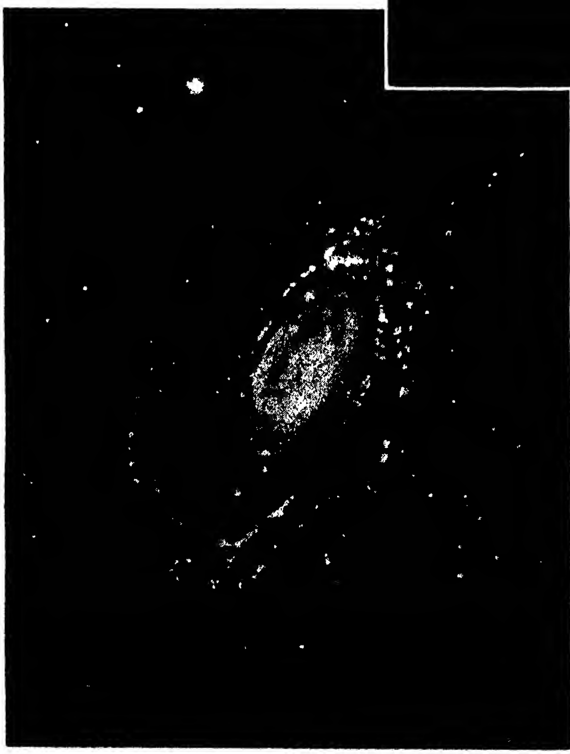

FIG. 31.—The Sun and Planets drawn to scale. The dark patches are calcium flocculi.

The sun is made up of chemical elements known on earth—a not surprising fact seeing that he and all his family of planets were in the distant past a single huge nebulous cloud. The sun is just one of 200,000 million other suns that make up our own universe or Milky Way (M.W.). It is $2{\cdot}4 \times 10^{13}$ mi. from his neighbour sun, *Proxima Centauri*, and $1{\cdot}76 \times 10^{17}$ mi. from the hub of our universe, the centre of the M.W., and this, in its turn, is $5{\cdot}28 \times 10^{18}$ mi. from the nearest "island universe" or galaxy, while $2 \times 10^{22}$ mi. of space lie between us and the farthest confines of the whole known or Einstein Universe. The mass of the sun is $1{\cdot}940 \times 10^{27}$ tons, and even the added weights of all the planets ($2{\cdot}95 \times 10^{24}$ tons) only bring the mass of the solar system to $1{\cdot}943 \times 10^{27}$ tons. The sun's far-flung planet, Pluto, is $3{\cdot}8 \times 10^{9}$ mi. distant, and the boundary of the solar system is possibly $4 \times 10^{9}$ mi. from the sun's centre. Other data are: dia., $8{\cdot}64 \times 10^{5}$ mi.; mid-sect. area, $6{\cdot}27 \times 10^{11}$ sq. mi.; surf. area, $2{\cdot}5 \times 10^{12}$ mi.; vol., $3{\cdot}2 \times 10^{17}$ cu. mi.; mean dens., 91·7 lb. per cu. ft.; cent. dens., 4,586 lb. per cu. ft.; mean dens. solar system, $8{\cdot}3 \times 10^{-11}$ lb. per cu. ft. (water, 62·37 lb. per cu. ft.); rot. period, 25·0 days; equat. veloc., 1·14 mi. per sec.; veloc. escape, 383·0 mi. per sec.; veloc. towards Delta, 12·65 per sec.; veloc. in M.W., 270 mi. per sec.; grav., 901·6 ft. per sec. per sec.; kin. energy, $4{\cdot}13 \times 10^{38}$ joule; $mc^2$ energy, $1{\cdot}78 \times 10^{47}$ joule; surf. temp., 6,000° C.; cent. temp. 20,000,000° C.; emission rad. energy, $3{\cdot}8 \times 10^{27}$ joule per sec.; loss of matter, $4{\cdot}45 \times 10^{6}$ ton per sec. (See also Figs. 33, 34, 35, 37.)

orbit is not a circle, but an ellipse (Fig. 26). The different positions of the earth as it goes round the sun are the causes of the seasons of the year by reason of the inclination of the earth's axis to the Ecliptic (Figs. 26, 27). *A* (Fig. 26) is the position at the summer solstice (about June 21), *B* and

FIG. 32.—The Whirlpool Nebula M 51, *N.G.C.* 5194 in the Constellation Canes Venatici.

The spiral nature of a nebula seen edge-on is difficult to make out. When, however, the central plane of such a nebula is at right angles to the line of sight, its spiral shape is easy to observe. Such a nebula is that depicted here, which is over 10 mill. mill. mill. miles away. Could we view our own Milky Way from a suitable position, it would almost certainly appear as a spiral nebula. The number of known extra-galactic nebulæ is 2,000,000, of which the majority are probably spiral. The 200-in. telescope which will penetrate $5{\cdot}8 \times 10^{21}$ mi. of space will in all likelihood reveal 16 million extra-galactic island universes. These nebulæ *appear* for the most part to be receding from us and from one another at velocities that increase with their distance. The average of forty separate nebulæ gave a speed of 384 mi. per sec. for each nebula. The majority were speeds of recession, only a very few being speeds of approach. The Whirlpool Nebula, as stated above, is more than ten million million million ($10^{19}$) mi. away. (See also Figs. 43 to 47.)



$B^1$ at the equinoxes (about March 21 and September 22), and $C$ shows the position at the winter solstice (about December 21).

We must not suppose that the earth turns upon a *material* axis such as that represented by the needle in Fig. 28. It swings round the sun in space, but while doing so it has also a rotatory motion; that is, it turns round, *as if* upon an axis, once every twenty-four hours.

We ought to try to grasp the extraordinary motions of our little earth: (*a*) it rotates on its own axis so that a point on the equator is moving at the rate of 1,000 miles an hour; (*b*) in going round the sun once a year its centre has to travel more than 1,000 miles a minute; (*c*) by the sun's attraction it (as well as all the other solar bodies) is carried through space at a rate of over 40,000 miles an hour. Perhaps not one of these three principal motions is conceivable by us; and yet, in addition, there are at least eight other motions, so that we need not wonder that the earth never journeys twice through the same place.

The moon is the earth's satellite, and its birth formed one of the great epochs in the history of our earth. Though we cannot trace this history to that point when the earth left the sun, we can trace a good deal of the history of the casting off of the moon by the earth. Sir George Darwin, son of the illustrious Charles Darwin, has worked out the details of this parting company of the two bodies with amazing accuracy. At that time the earth must have been in a somewhat plastic if not fluid state and, moreover, rotating very much faster than it does at present, otherwise the centrifugal force due to its rotation would not have been able to throw off the moon. According to Sir George Darwin a great treacly mass became detached from the spinning earth, much as a drop of water flies off from one of the tassels of a spinning mop (see Fig. 30). Now, just as the moon causes tides on the earth to-day, so the earth caused tides on the moon. Sir George goes on to describe how immediately after the moon was thrown off, and while it was revolving very close to its parent, colossal tides were raised on each of the two semi-fluid bodies. A twofold reaction resulted from the tidal friction: the moon's orbit became twisted from a circular into an eccentric form, while both earth and satellite were forced farther and farther apart. Even at the present period of the earth–moon history, when our satellite is in perigee—that is, when she is nearest to us—the tidal effects are much greater than when she is in apogee.

Yet another effect of the tidal reactions consequent upon their mutual attraction is a disharmony between their periods of rotation and the period of revolution of each round the other. "Something like fifty-seven million years ago," says Professor Turner, "there was only one day

in the month; that is, the moon was running round the earth as quickly as the latter rotated on its axis."

As applied to the formation of suns and their attendant planets, Laplace's theory is now considerably modified. In recent times we have discovered more than a hundred thousand nebulæ in the heavens, so that we have full confidence in regarding them as the stuff out of which worlds are made. The "nebular hypothesis" is therefore as strong as ever so far as the majority of star-systems are concerned. Where it breaks down, as already stated, is with reference to the general conformation—the relative masses, motions and positions—of the several members of our own family of sun and planets, to account for which one or other of the two tidal-disruption theories is now held by scientists. These theories assume that some billions of years ago a star of greater mass than our sun came within close proximity, say a few million miles, of it. Even if such a star came within 5,000,000 miles, it would exert a "tide-raising" force some 16,000 times greater, relative to surface gravity, than that of the moon on the earth. As the combined result of the "pull" of the star and the internal disruptive forces set up thereby in the interior of the sun, great masses of the latter were expelled excentrically. Chamberlin and Moulton think this occurred at two antipodal points on the sun's equator. The approach and retreat of the passing star imparted a tangential motion to the two arms of torn-out gaseous matter, thus causing them to revolve around the central mass of the sun, and prevented their falling back into it after the star had passed on. These two gaseous arms, eventually condensing at various points, became the planets and satellites, etc. Such is the *two-armed tidal-disruption* or *planetesimal theory.*

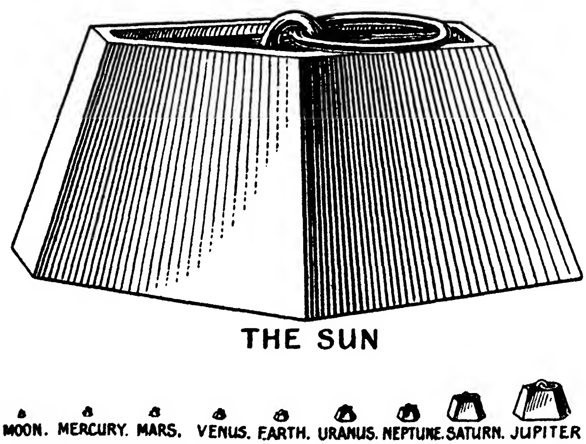



FIG. 33.—Weights representing the Masses of the Celestial Bodies (Pluto has been omitted). For the actual mass measurements of the Solar system see Fig. 31.

Sir James Jeans, on the other hand, assumes that, since the tidal upheaval must have been principally manifested on that face of the sun

nearest the passing star, there resulted from the mutual "pull" one long cigar-shaped filament of gaseous matter. This, he tells us, provided a fit playground for the processes of "gravitational instability." So condensations occurred in the "cigar," the larger ones in the neighbourhood of the central bulge, the smaller about the two pointed ends, and these ultimately became the planets; the larger ones being accommodated in the bulge of the cigar, the smaller ones towards the narrower regions. Such is the *one-armed tidal-disruption theory* of Sir James Jeans (see Fig. 31).

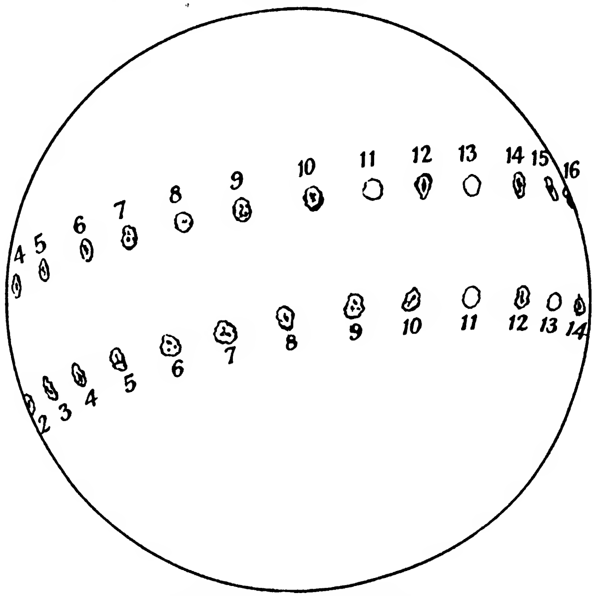


FIG. 34.—Two Sun-spots, showing their changing positions in consequence of the Sun's rotation.

If you examine very closely the photograph (on page 32) you will see that the nebula has two great fiery spiral arms winding round it. This is the general shape of nebulæ, a shape that indicates the real way worlds are made. You can see the fiery material of the arms actually gathering at certain points, as if to form planets, while the central mass is turning into an immense sun or group of suns. It is a living picture of worlds in the making.

Let us now turn to the history of the sun. In addition to the sun, the solar system consists of nine planets, thousands of planetoids or asteroids, meteors, comets, cosmic dust, molecules, atoms, proto-atoms, and radiations.

So huge is the sun as compared with the subordinate members of his family that if all the planets and satellites could be piled into one mass they would amount to but a small fraction ($\frac{1}{740}$) of the weight of the sun (Fig. 33). We must remember that all the matter now forming the solar system once existed as a huge nebulous mass, $\frac{1}{200,000,000}$ of the density of our lightest gas, hydrogen, extending far beyond the orbit of Pluto.

In Fig. 31 we see some sun-spots, but little idea is conveyed of their vast size. In Fig. 34 are *two* spots, one above and one below the equator,

*Royal Observatory, Greenwich.*

Fig. 35.—A Sun-spot. (See caption to Fig. 36.)

that have been drawn sixteen times as they were being carried round by the rotation of the sun. In fact, they afford us the means of measuring the time which the surface of the sun takes to rotate. Fig. 35 is a photograph of one of the largest sun-spots. What these spots are, how they are caused, and whether they affect the weather on our planet or not, is still undetermined, but they are undoubtedly magnetic, for two adjacent sun-spots behave like the opposite poles of a horse-shoe magnet; in fact, every "sun-spot" is linked up with some other spot having an opposite kind of magnetism. The eleven-and-a-half-year magnetic storm cycles that synchronize with an exacerbation of sun-spot activity are almost certainly causally related to the corresponding periodicity of our terrestrial magnetic disturbances.

When there is an eclipse of the sun, remarkable flame prominences are seen on its surface, as shown in Fig. 36. With their perfected instruments modern astronomers can observe these flames at any time, without having to wait for an eclipse. They can even photograph the great storms in the sun's dense atmosphere. These flames are over 124,000 miles high.

This brings us to the very interesting question of the source of the heat of the sun. Heat is only a form of energy, and energy, like matter, cannot be created out of nothing. We have therefore to inquire whence comes the energy which supplies the heat of the sun. To grasp, even partly, what is implied by the amount of heat radiated by the sun we must gain

some notion of the sun's size. Its diameter is 865,000 miles—*i.e.*, one-hundred-and-eight of our earths could be threaded, like beads, along it. Its surface area is 12,000 times, while its volume or bulk is 1,300,000 times, that of the earth. In fact, were the sun hollow, there could be placed inside it the earth together with the moon circling round her, yet not half of the sun's interior would be occupied (Fig. 37).

Note, again, how small are the earth and moon as compared with the sun-spot and the flame prominences.

Now, with this representation of the size of the sun, let us try to form some idea of its heat. The sun is not a fire deriving its heat from the combustion of some material, as does an ordinary fire when coal and wood are burnt up. It would require the burning of thousands of billions of tons of coal every second to produce the present heat and light of the sun, the light alone being 3,230,000000,000000,000000,000000 ($3{\cdot}23 \times 10^{27}$) candle-power.

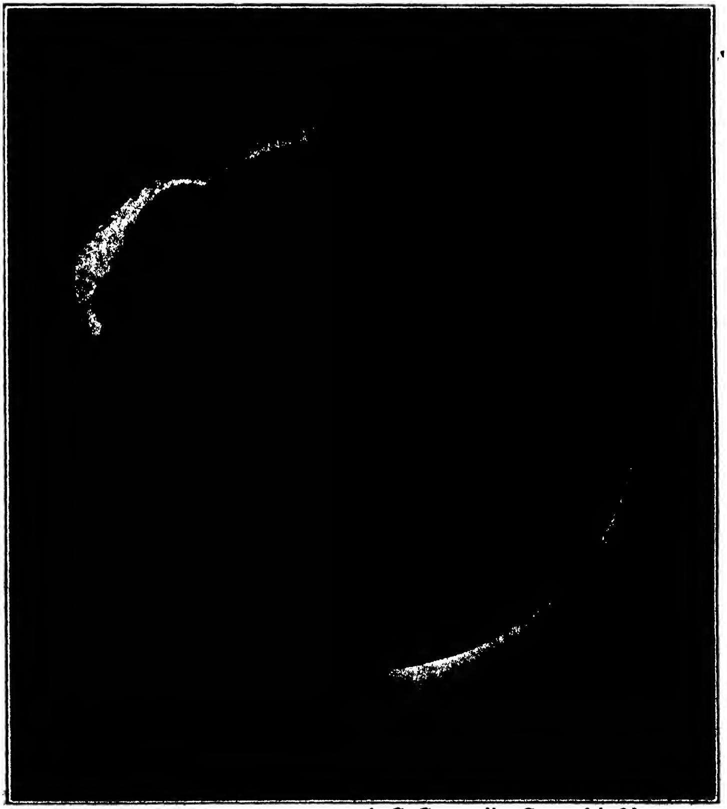


Fig. 36.—The "Ant-eater Prominence."

The whole sun is gaseous, even the centre, despite the pressure here of 150,000 million lb. per sq. in. The surface gases and clouds are rent by storms and explosions, and piled up in huge heaps, the former representing the sun-spots 500 to 50,000 mi. long (see Fig. 35), the latter 30,000 mi. high. The spots recur at intervals of 11·2 years, the electrons expelled from the sun at max. spot period causing the N. and S. Auroras and extensive magnetic disturbances all over the earth.

*A. C. Crommelin, Greenwich Observatory.*

If the sun were a solid mass of coal, and there were enough oxygen to burn it, it would only keep up its present rate of radiation for 2,800 years. But the sun has been giving out its enormous heat for over seven-and-a-half million million years, and can continue to do this for millions of millions of years to come. So it is evident that combustion is not the source of its heat.

If the sun has contracted to its present volume from a vastly larger volume of gaseous matter that, in all probability, more than filled up a sphere with a periphery represented by the orbit of Pluto, such contraction must have caused an enormous rise of temperature through conversion into the kinetic energy of heat of the potential energy of the widely diffused myriad particles, as they gradually settled towards a common centre of gravity. We know that the sun is shrinking so rapidly that its diameter is a mile shorter every eleven years (Fig. 38). Since the wise Hammurabi sat on the throne of Babylon, 2,220 years B.C., the diameter of the sun has diminished some 375 miles; while in a million years the shrinkage has amounted to approximately 100,000 miles. Helmholtz considered that contraction of the sun accounted for the whole of its temperature, but Kelvin showed that the shrinkage that has already taken place could only maintain the sun's heat for about 50 million years, whereas geology alone tells us the sun must have been giving out light and heat for a vastly longer period than this. Since contraction is but a minor source of the sun's heat, we must search for other causes. The impact of meteors

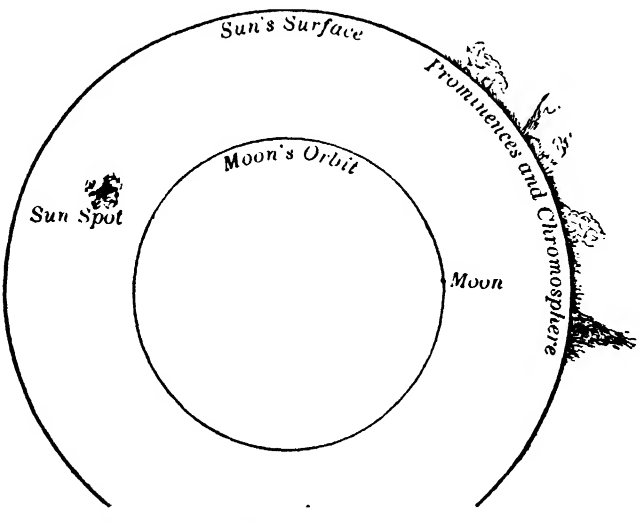



FIG. 37.—Dimensions of the Sun compared with the Moon's Orbit.

The prominences and sun-spots shown here and in the last three figures are, from the terrestrial standpoint, enormous in dimension. A prominence may be 30,000 or 40,000 mi. high, 6,000 or 7,000 mi. thick, and occupy a base of hundreds of thousands of miles. A sun-spot may be 50,000 or 60,000 miles across. Our whole earth could easily be hidden in an average prominence, while six to eight earths lying side by side could be dropped into one of the larger sun-spots without touching its edges.

ever raining down on the sun's surface is also inadequate. Sir James Jeans has pointed out that even the fall of our earth into the sun would only maintain its extravagant rate of radiation for 100 years. If the sun's maintenance of heat were dependent upon the infall of matter, this would have to be of such a quantity that the sun's weight would be doubled in 30 million years, whereas we now know that our luminary is actually *losing weight at the appalling rate of* 360,000 million *tons a day*, or about 4 million *tons each second.* The sun that sees this edition (1948) through the press is lighter by $1{\cdot}12 \times 10^{16}$, or more than 10,000 million million tons, than the sun that shone on the Indian Mutiny in 1857! Despite such loss there is no visible shrinkage of our orb with the passing of the centuries. This is due, of course, to its prodigious mass of 2,000,000000,000000,-000000,000000 tons. The radiation of energy from, and consequent loss of weight of, the sun was, says Jeans, still more furious in the past, though in the future it will get less and less—just as the sand in an hour-glass runs out fastest at the start and slowest towards the end. A good idea of the rate at which our luminary is wasting his substance in riotous radiation may be gathered by looking at the Thames as it rushes seaward under London Bridge and reflecting that there would have to be 10,000 such rivers flowing past to equal the present pouring away of matter into space by the sun. Other suns than ours, more massive and hotter, are losing weight even more rapidly. According to Jeans, *S. Doradus*, in the Magellanic cloud, is emitting radiation so lavishly that it is losing weight 300,000 times faster than is our sun.

Sir G. H. Darwin says: " It does not seem unreasonable to suppose that 500 million to 1,000 million years may have elapsed since the birth of the moon " from the earth. This demands that the age of the sun must be vastly longer than physicists have hitherto allowed. For half a century the solar time-spans of the geologists could not be squared with those of the physicists. But the discovery of radium was soon followed by evidence that contraction of the sun and falling meteors are not the only sources of the sun's heat. Radium is, perhaps, a million times more powerful than dynamite. Twenty-two ounces of radium would furnish enough energy to tow a ship of 12,000 tons a distance of 6,000 sea miles. Now we know there are radio-active forces in the earth, and it is certain that the sun is intensely radio-active. If there were as much radium in the sun as would be equal to one three-hundred-thousandth part of its mass, it would keep its heat going for 1,000 million years. Nevertheless, contraction, fall of meteors, and radio-activity, do not suffice, even in combination, to keep up the sun's extravagant emission of energy.

Modern physics is able to suggest yet another process capable of greatly extending the life of a luminous—that is, energy-radiating—star; it is the actual annihilation (so called) of matter, which in reality denotes its transmutation into radiant-energy or light. This is the general principle underlying the mechanism of the atomic bomb. Obviously a heavy star can only change into a lighter one if material is removed; and this is effected, say modern astro-physicists, through annihilation of the atoms and their transformation into radiations. *The radiations possess weight*, but once they have left the luminous body and become extra-stellar, their weight no longer affects the star. By annihilation—a particularly misleading term to be used by physicists—is meant, not the conversion of something—matter, electrons, protons, radiation—into nothing (a process as impossible as the creation of something out of nothing), but the disappearance of something *as such* and its reappearance under another form. This book, if burnt up, is annihilated as a book, but most of its mass remains as smoke, vapour, and ash, a minute fraction being converted into heat, light, and other radiations; and these several components could theoretically be resynthesized into another edition of the work! "The two fundamental corner-stones of nineteenth-century physics," says Jeans, "the conservation of matter and the conservation of energy . . . are replaced by the conservation of a single entity which may be matter and energy in turn. Matter and energy cease to be indestructible and become interchangeable. . . . Heat, light, electricity, have all in turn proved to be forms of energy; the annihilation hypothesis only proposes to add another to the list, so that matter itself also becomes a form of energy."

At the birth of the sun, about seven-and-a-half million million years ago, energy became stored up in the protons, neutrons, and electrons of which its atoms were constituted, and ever since that time the sun has been lavishly pouring out energy and losing matter, and will continue to do so for millions of millions of years to come. This energy, says Jeans, is being emitted at the sun's *surface* at a rate of 50 horse-power per square inch. Yet only one atom in every 15,000000,000000 is broken up *per year* to produce this terrific stream of energy. How is this explained? The energy radiated away at the surface really comes from the whole depth of the sun down to its centre. The 50 horse-power manifested at each square inch of sun-surface has been produced inside a cone of sun material 433,000 miles long, whose apex is the centre of the sun, and base a circle on his surface with an area of a square inch. In such a cone Jeans computed the number of atoms to be $10^{33}$, or 1,000,000000,000000,-000000,000000,000000, and out of this vast number 2,000000,000000

break up every second. The overwhelming proportion of the sun's heat is caused by this disruption of atoms within its interior, and our enjoyment of his heat is consequent upon the very minute fraction, $\frac{1}{2,200,000,000}$ of the whole, which our earth intercepts. The energy set free by atomic disintegration is 18,000 million times greater than that liberated during ordinary combustion. A pound of coal burned in our grate might warm us for a few minutes and perhaps, in addition, boil a couple of eggs, but the same pound atomically disintegrated would, says Jeans, " keep the whole British nation going for a fortnight, domestic fires, factories, trains, power-stations, ships and all ; a piece of coal smaller than a pea would take the *Mauretania* across the Atlantic and back."

Eddington and Emden have calculated the central temperature of the sun to be 31,500,000° C. Jeans, by independent measurements, arrived at the figure 55,000,000° C. We need not concern ourselves as to which of the two figures is the more correct; sufficient for us is Sir James Jeans's assurance that if a bit of the sun's core the size of a pin's head could be brought to our earth, it would instantly consume every living creature within a radius of 1,000 miles.

One consequence of the sun's decrease in mass and weight is a lessening in the " pulling " force on his family of planets, with the result that all of these, including, of course, the earth, are receding from it in an ever-widening spiral. The earth's recession is small, only $\frac{3}{8}$ inch per year. Nevertheless, on the geological time-scale such an amount is not negligible, for in a million million years the earth will be 5,700,000 miles farther from the sun; and this, coupled with the sun's diminished heat-producing power, will lower our surface

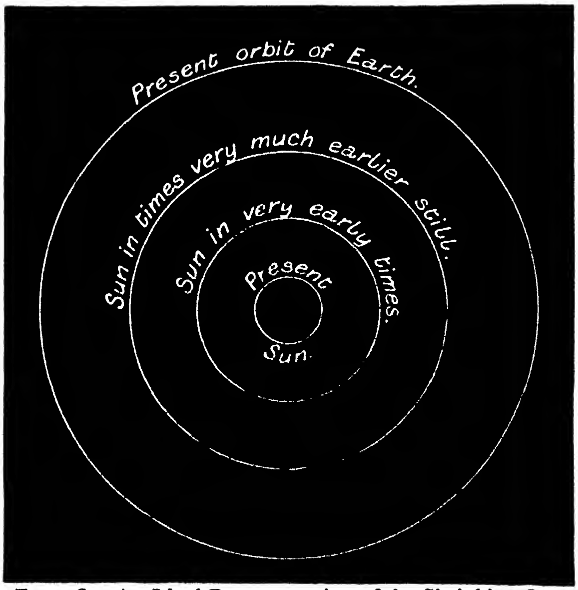



FIG. 38.—An Ideal Representation of the Shrinking Sun. (After *Sir Robert Ball.*)

FIG. 39.—A Comet.

Orderliness preponderates in the solar system. The vast majority of the nine planets, the twenty-eight moons, the thousands of asteroids, the rings of Saturn, revolve and rotate in a manner conformable, as regards plane and direction, with the rotation of the sun. The renegades are the Uranus system, the satellites of Neptune, outer satellites of Jupiter and Saturn, and, lastly, the comets. These last are the debris of the solar system in the making, disjecta from the larger planets, especially Jupiter and Saturn. Comets move in exceedingly elongated elliptical orbits around the sun. They are visible and bright only when near the sun (perihelion). Each of these bodies is made up of a central *nucleus* of sodium, iron, and nickel surrounded by a gaseous mass of cyanogen (CN) and carbon monoxide (CO), the *coma*; from the last-named there extends the well-known *tail*, which invariably points away from the sun owing to the pressure of light. The weight of an average comet is anything from 30 million to 10,000 million million tons. The diameter of the coma is constantly altering. In the case of Halley's comet, *e.g.*, the diameter was 13,000 mi. on Sept. 12, 1909, and this on Dec. 14 had increased to 220,000 mi.

temperature about 30° C., and man, if still surviving, will be experiencing another glacial period.

Before we turn to consider the great universe of stars, of which our solar system is a mere speck, we ought to say a few words about comets and meteors.

The origin of comets is not yet absolutely settled, but the general conclusion among astronomers is that they do not come from outer space, but belong to the sun's family; they are, in fact, his aberrant offspring. The few cases where they pass the sun in apparently unclosed curves, such as the parabola and hyperbola, are probably due to disturbances produced by planets. Comets are composed of gases and of myriads of

solid particles varying in size from specks of dust to push-balls. They react in a striking manner, on the one hand to the sun's gravitational attraction, and on the other to repulsion caused by his radiation. Hence, while the head of the comet, containing the heavier particles, is pulled in a curve round the sun, the tail, containing the lighter particles, is "pushed away," so to speak, to that side of the comet's head farthest from the sun. The solid particles of the comet reflect the sun's light, but the gases are self-luminous and glow like those in an electrified vacuum-tube, and probably for the same reason. Though the total mass of all the known comets is possibly less than that of the moon, yet a single comet spans enormous distances of space, sometimes over 100 million miles.

Meteors, or "shooting-stars" as they are popularly but erroneously called, are solid bodies principally composed of iron, and varying in size from dust to masses of hundreds of tons. They are relics of the primeval fire-mist originating our solar system, the leavings and parings left over after the other worlds had taken form, or possibly the flotsam and jetsam of one of these wrecked in the making. Thousands of millions are caught annually by our earth, and of these only about one per cent are visible. Those that enter our atmosphere at very high velocities are quickly raised by friction to incandescence, and many of them are completely volatilized. The weight of the earth is increasing at the rate of 100,000 tons a year in consequence of this meteoric rain, and as for the sun, 2,000 tons are falling into it every second!

When the relative velocity of a large meteor is sufficiently low to enable it to resist the action of our atmosphere, it completes its fall to the earth and is then called an aerolite or meteorite.

Fig. 40 shows the celebrated meteorite which fell at Gross Divina, Hungary, in 1837, and weighs about twenty-four pounds. But this is puny in size compared with the meteorite which fell in Siberia, in 1908, and which Sir James Jeans tells us "set up blasts of air which devastated the forests over an enormous area, while the shock of its impact on the solid earth caused waves which were recorded thousands of miles away." A huge crater in Arizona, about 420 yards in circumference, is said by scientists to have been caused by the fall of a yet larger meteorite. The finest collection of these bodies in the world is at Vienna, but the London, Paris, and Yale museums all have good collections. Our interest lies in the message which these visitors from far-distant regions bring to us, for they tell that all nature is one. Twenty-seven of the chemical elements, including argon and helium, have been found in them, but not a single *new element*. Many of their *minerals*, however, are not found on the earth, but for

Fig. 40.—A Meteorite.

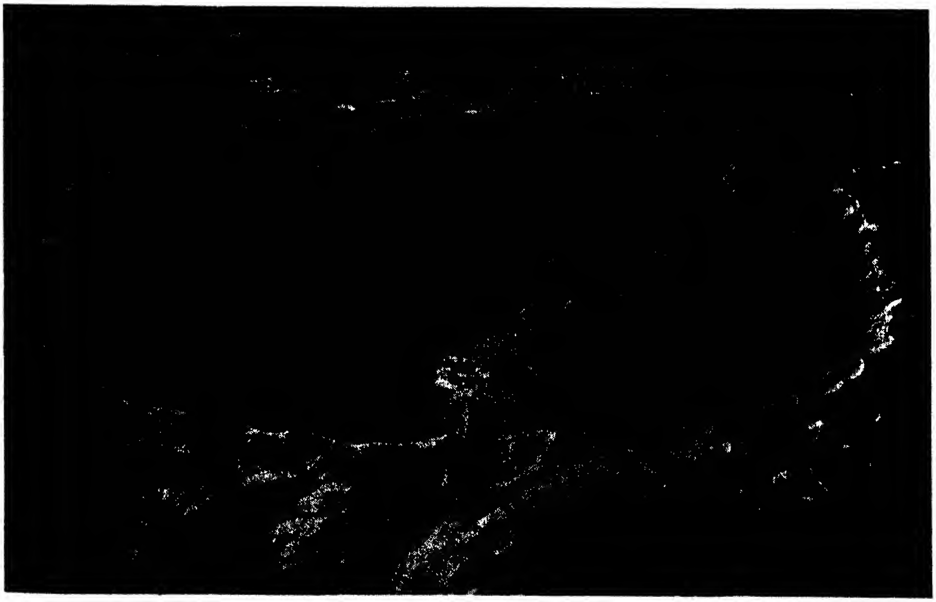
Meteorites are of two chief kinds, iron and stone, according to the predominating chemical elements composing them. They fall on our earth every day of the year, but special showers of them occur when our globe happens to pass through the orbit of a stream of meteors. Many meteors are the remains of some disintegrated comet. Biela's comet, *e.g.*, is a case in point. It was due to reappear in 1872, but failed to do so, its place being taken by a magnificent meteoric display. Dr. Davidson, F.R.A.S., says there are "at least eight meteor streams associated with comets." Most meteors are but the size of acorns to footballs, and fail to reach the earth's surface (fortunately for us) through dissipation into vapour by friction with the atmosphere. In Arizona a huge meteorite fell on the earth, producing a crater 570 ft. deep and 420 ft. dia. A much larger one fell in Siberia on June 30, 1908, weighing many hundreds of tons. It devastated, by fire and wind-blast, an area of about 4,000 sq. miles.

the most part they bear resemblance to terrestrial ones of volcanic origin. In short, meteors present us with no new elements, only with new combinations.

When we turn to the stars, words fail to convey any idea of their grandeur. We are dazed by their myriad numbers, colossal sizes, and vast distances. Among some of the finest spectacles in the heavens are the Globular Clusters, of which about a hundred are known. Each of these contains hundreds, even thousands, of stars, among which are those very mysterious types, the *Cepheid Variables*, whose alternating luminosities have enabled Professor Shapley to determine the distances of the clusters. And terribly remote they are, on the very confines of the known universe, the nearest, *Omega Centauri*, being 22,000 light-years away, while the farthest, *N.G.C.* 7006, is 220,000 light-years distant. These star-clusters all look much alike, and *M.* 13 in Hercules, shown in Fig. 42, may well stand for any of them. Of the total number of 10,000 stars visible without a telescope, about 3,000 can be picked out with the naked eye from any one position on a clear moonless night. Nine millions are brought into view by a moderate telescope and close on a thousand millions by the 100-inch one. But the marvellously delicate apparatus of science brings a yet greater multitude of stars within the ken of man. We are told that in our own galactic system alone there are 400,000 million suns. The late Sir Arthur Eddington, using the apparent speed of recession of the nebulæ

out beyond our Milky Way as a basis for his calculations, estimated the number of stars in our own universe, as outlined by the Milky Way, to reach the figure $1{\cdot}1 \times 10^{22}$, 11,000,000000,000000,000000. Jeans's estimate is even higher—$2{\cdot}0 \times 10^{24}$, 2,000000,000000,000000,000000.

The latter of these two brilliant British astronomers gives us a vivid illustration of this grand host of luminous orbs and a very profound impression of man's relationship to them. Suppose the stars to be represented by grains of sand scattered over an area equal to that of England, they would form a layer hundreds of yards deep. When we reflect that on this scale our own earth would be represented by one-millionth part of one of these grains, then, adds Jeans, " our mundane affairs, our troubles and our achievements begin to appear in their correct proportion to the universe as a whole." A few scientists, including notably Jeans and Eddington, apparently on the basis of evidence alleged to be forthcoming from the mathematics of Relativity, assume and teach that the universe not only occupies a finite portion of *space*, but is subjected to a limited period of existence in *time*. They argue, in effect, that at some instant in the far past the universe was created out of nothing, and that in the not very distant (astronomically speaking) future it is



*H. J. Shepstone.*

FIG. 41.—The Meteor Crater in Arizona.

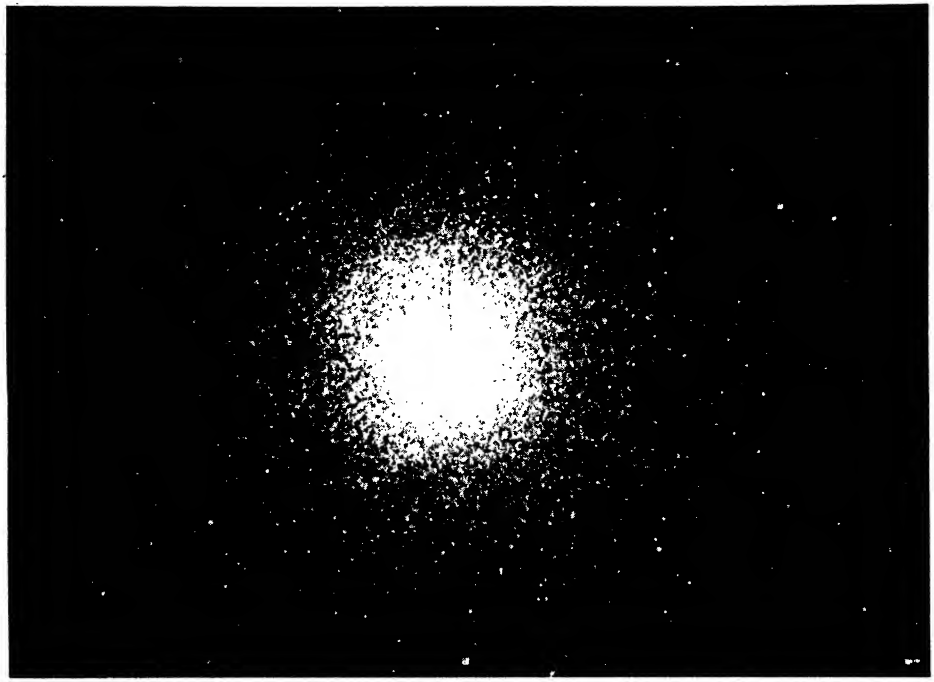


FIG. 42.—The Cluster in Hercules (*M.* 13). (After *Flammarion.*)

Globular Clusters are chiefly congregated around the centre of the Milky Way or Galactic Sphere. Each is $10^{14}$ to $10^{15}$ mi. dia., and contains many thousands of stars like our own sun. Their distance from us varies from $10^{17}$ mi. to $8 \times 10^{17}$ mi. One of the nearest is shown above, *N.G.C.* 6205, *M.* 13 or *Omega Centauri* in Hercules. Another cluster about the same distance from us is 47 *Tuscanæ.*

doomed to a definite end of its " life "—that is, to an eternal darkness, stillness, and inactivity consequent on the degradation of its matter-energy complex to a common dead level. But other scientists—and, it would appear, the vast majority of them—refuse to admit that relativist predictions of a dead universe poised amid a nigrescent nothingness warrant the abandonment of the well-founded and well-tried Spencerian hypothesis of an infinitely extended and enduring universe. To them Jeans's cosmic totality of $2 \times 10^{24}$ luminous stars will be less than a drop in the ocean.

With a three-sided column of glass such as one of those forming a chandelier you can split up " white " sunlight into its seven component colours—violet, indigo, blue, green, yellow, orange, and red. The seven-banded strip of colours produced by the glass prism, as well as that arch of colours called the rainbow produced by the raindrops, is called a

spectrum. Incandescent bodies and gases give various spectra according to their nature, and by means of the spectroscope—which is but a telescope connected up with a series of prisms—chemical elements can be identified. This instrument has done even more for astronomy than the telescope, and among its great achievements is the power to distinguish between star-clusters and nebulæ. Nebulæ are of three kinds: (1) *Planetary nebulæ*, of which only a few hundreds are known, are probably stars surrounded by vast atmospheres made luminous by the stars near them. They all lie *inside* our Milky Way or Galactic Circle. (2) *Galactic nebulæ* also lie inside the Milky Way; they consist of vast clouds of green-coloured, glowing gases that often envelop a whole constellation of stars. Besides hydrogen and helium, they contain matter in such pre-atomic states as ions, electrons, protons, neutrons, etc. (3) The colossal *extra-galactic nebulæ*—so called because they lie outside our Milky Way—are usually white in colour and spiral in form. They are similar in general shape, as well as in the number of stars they contain, to our own muffin-shaped universe bounded by the Galactic Circle. Some two million of these nebulæ are visible in the 100-inch telescope, each containing enough matter to make 2,000 million stars. According to Jeans, the size of these nebulæ is of the order of "hundreds of thousands of millions of millions of miles." While some of the matter within them consists of relatively dense stars, yet other matter has a density one-millionth of that which we can obtain in our vacuum tubes. Fig. 45 shows the great chaotic nebula in Orion, one of the largest bodies in the heavens.

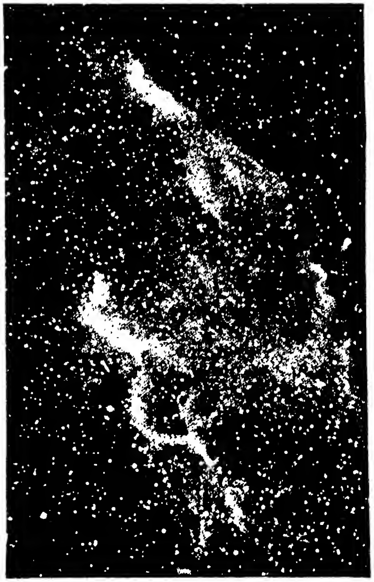


FIG. 43.—A diffused Nebulosity. (*N.G.C.* 1499: in Perseus.)

Diffuse nebulæ are composed of cosmic dust and gases (hydrogen and ionized oxygen). The best known is that in the Pleiades, or in Orion, the former $1{\cdot}4 \times 10^{15}$, the latter $2{\cdot}27 \times 10^{15}$ mi. from us. Like the planetary nebulæ, they do not shine by their own light, but are lit up by that from the brilliant stars in and around them. The great diffuse nebula in Argo is over $10^{16}$ mi. in diameter. They are of extremely low density; the *Wolf Nebelnest* Nebula, *e.g.*, is so tenuous that it is $1{\cdot}4/10^{27}$ times the density of water; a cubic mile of it contains but one ten thousand millionth part of a grain of matter.

The spiral nebula depicted in Fig. 32 (p. 32) gives us some idea of the way in which heavenly bodies began to rotate and revolve.

Fig. 46 shows a "ring nebula"; it is probably a spiral seen edge-ways. Fig. 47

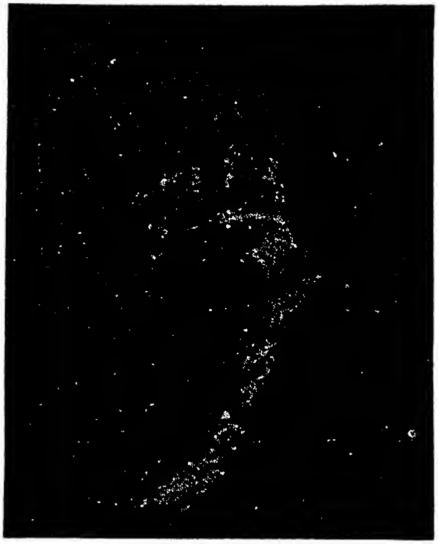


FIG. 44.—An irregular Nebula.
*N.G.C.* 6992; in Cygnus.
(After *Dr. W. E. Wilson.*)

The visible forms of nebulæ are infinite in variety. They comprise circular, globular, ellipsoidal, spiral, bifid, and tripid nebulæ. There are nebulæ resembling a wheel, double wheel, ring, a horse-shoe, horse's head or dumb-bell. Above is an irregular-shaped nebula.

is the nebula in Andromeda. This stupendous object, one of the most conspicuous of the extra-galactic nebulæ that are scattered through space at average distances apart of 63,000000,000000 miles, is just visible to the naked eye. We see it, not as it is now, but as it was 900,000 years ago! It makes a complete revolution in 16 million years. On first thoughts this might seem slow progress, but to accomplish it the outlying parts of the nebula have to hustle along at a speed of well over 100 miles a second! This body has a mass equal to 5,000 million, and a luminosity equal to 660 million of our suns (Jeans).

Could anything more marvellous be discovered by man than that, in a body of such dimensions, the same law of Evolution prevails as in the speck of living jelly that gives rise to himself?

Modern science views the universe as made up of some 94 serially related elements, from hydrogen and helium at the light end, to radium and uranium at the heavy end of the series.

Formerly the number of chemical elements was believed to be 90, but during the last two decades this number has been increased to 94 by the discovery of four more elements—masurium, virginium, radio-transuranium, and normal transuranium. A brief account of the finding of these elements will be of interest to the reader. Masurium (Ma) has atomic number (A.N.) 43, and mass number, which gives the relative atomic weight (A.W.) that has not as yet been certainly ascertained, though it is probably in the neighbourhood of 100. Its structural formula may therefore be written $_{43}\mathrm{Ma}'^{100}$. Masurium was discovered in 1925 by Noddack, Tacke, and Berg, who separated it from the ore *Columbite*. It is named after a prince of Masurenland, in E. Prussia, and belongs to the manganese family of chemical elements. In the periodic table it lies between molybdenum, $_{42}\mathrm{Mo}^{98}$, and ruthenium, $_{44}\mathrm{Ru}^{102}$. By bombarding the former element with neutrons ($_0n^1$) and deuterons

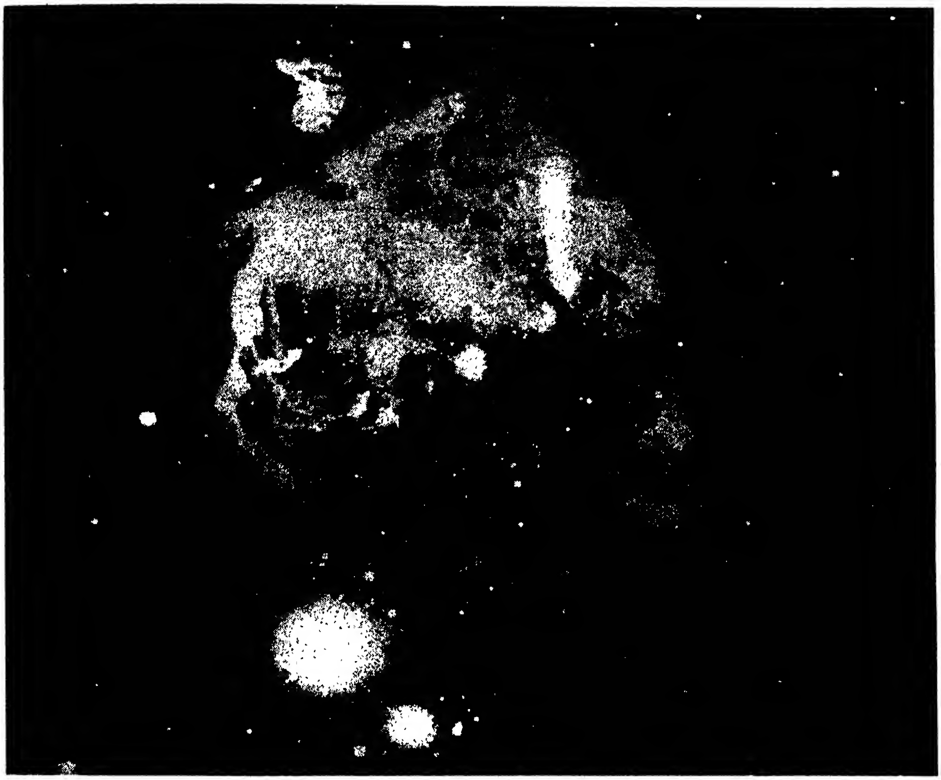


FIG. 45.—The great Nebula in Orion. (*Lick Observatory.*)

The great nebula in Orion, *A. Orionis*, is a vast tenuous cloud of gas some $10^{15}$ mi. diameter, and with a mass of about $4 \cdot 3 \times 10^{36}$ tons. This mass is spread over a volume of $7 \cdot 5 \times 10^{44}$ cubic mi. of space, equivalent to a density of a grain of matter in each 11·0 cu. mi. of nebula. This nebula is just visible to the naked eye.

($_1H^2$), accelerated to a high velocity by means of the cyclotron, Segré succeeded in isolating the missing element masurium. It was Professor Papisk, of Cornell University, who discovered Virginium (Vi). Its A.N. is 87, its A.W. 224, and its structural formula is, therefore, $_{87}Vi^{224}$. It lies between niton or radon, $_{86}Rn^{222}$, and radium, $_{88}Ra^{226}$. It was Fermi, in 1938–1939, who proved the existence of—or rather who "created" or evolved—two elements beyond the (up to his time) last and heaviest element, uranium. Their genesis is indicated thus:—

| | | | |
|---|---|---|---|
| (*a*) $_{92}U^{238}$ + | $_0n^1 \longrightarrow$ | $_{92}U^{239}$ + | $h^0$ |
| Normal Uranium. | Neutron. | Radio-uranium. | Gamma photon |

$(b)\ {}_{92}U^{239} \longrightarrow {}_{93}X^{239} + {}_{-1}e^{0}$
Radio-uranium. Radio-transuranium. Electron.

$(c)\ {}_{93}X^{239} \longrightarrow {}_{94}X^{239} + {}_{-1}e^{0}$
Radio-transuranium. Normal transuranium. Electron.

That is, (*a*) normal uranium bombarded by neutrons develops into a radio-active uranium and the energy of a gamma radiation. (*b*) This radio-uranium, by expelling an electron, becomes a radio-active trans-uranium, which (*c*) by shedding another electron, evolves into normal transuranium.

In the Appendix further examples will be given of the conversion of one element into another as well as of elements into energy, and vice versa.

Other entities that form the basic structure of the universe—here as building stones for the erection of bodies of ever greater and greater complexity; there as the dust and debris so to speak, resulting from the break-down of these complex bodies and their return to those of ever and ever decreasing complexity—are electrons and positrons, protons, neutrons and mesotrons, photons or radiations, these last-named extending over a vast scale of wave-lengths, from the long hertzian, " wireless " and dark-heat waves, through the medium visible light and ultra-violet waves, to the short X-rays, gamma and cosmic waves.

These entities are assumed to be, directly or indirectly, convertible, and each of them possesses mass and weight. Modern thermo-dynamics has led to two conflicting views of the future of the universe. Jeans believed that the universe is doomed to a final heat-death; like a clock-weight, its energy is running down, so that at last it must come to a stand-still, when its energy is at a dead level and no longer available. Other cosmologists, however, take an opposite view, and one far more consistent with the principle of continuity which appears to underlie all Nature's processes. They believe, as has indeed been suggested above, that in her great laboratories matter is not only disappearing and reappearing as radiations, but that the latter are in corresponding degree,

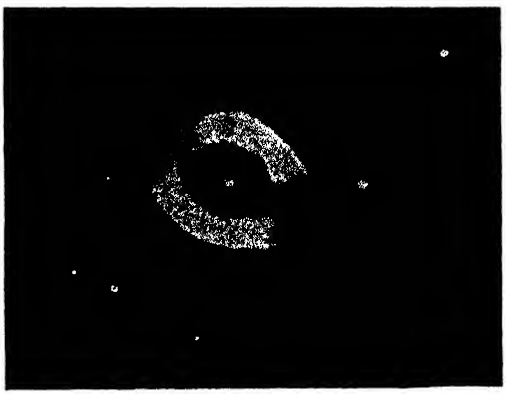


Fig. 46.—The Ring Nebula in Lyra. (*Lick Observatory.*)

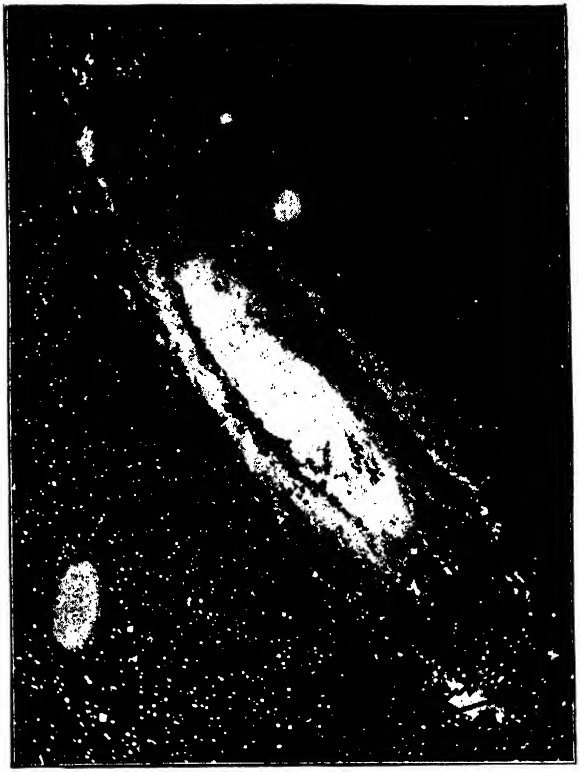


FIG. 47.—The Nebula in Andromeda.

(*After a photograph taken at the Yerkes Observatory by Prof. Ritchey.*)

The nebula in Andromeda, *M.* 31, is an "island universe" or extra-galactic spiral nebula of which some 75 million are known to exist, each containing 100,000,000,000 suns like ours. Despite its distance of 6 million million million miles from us, it is one of the nearest extra-galactic nebulæ to us. In many features it resembles our own Milky Way Universe. The following are the main points for contrast between our own Galactic Circle (G) and the Andromeda Nebula (A): Dia. mi. A., $1{\cdot}0 \times 10^{17}$; G., $1{\cdot}5 \times 10^{17}$. Vol. cu. mi. A., $5 \times 10^{50}$; G., $1{\cdot}7 \times 10^{51}$. Mass (wgt.) tons: A., $1{\cdot}0 \times 10^{37}$; G., $3{\cdot}3 \times 10^{44}$. No. of contained suns: A., $1{\cdot}0 \times 10^{11}$; G., $2{\cdot}0 \times 10^{11}$. Dens. lb. per cu. ft.: A., $3 \times 10^{-24}$; G., $7{\cdot}4 \times 10^{-24}$. Rev. period. years: A., $1{\cdot}6 \times 10^{7}$; G., $2{\cdot}5 \times 10^{8}$. Path covered by peripheral stars in one year: A., $3 \times 10^{17}$ mi.; G., $3 \times 10^{18}$ mi. Vel. rev. mi./sec. of peripheral stars: A., 186; G., 184.

Dist. covered by our sun during one rev., $5{\cdot}65 \times 10^{17}$ mi.

but at prodigious distances from their site of origin, disappearing and reappearing as matter. While the former processes are undoubtedly taking place in the central furnaces of the sun and stars, the latter processes, other cosmologists, notably Millikan, believe to be taking place in the intensely cold depths of extra-galactic space. On such a view the universe becomes a cyclic whole, without beginning or end, the fundamentals of its total matter-energy content being in perpetual flux—a periodicity of evolution upwards towards greater complexity and differentiation, and devolution downwards towards greater simplicity and disorganization. In the cosmos, as the astronomer Flammarion has aptly remarked, are both cradles and tombs!

# CHAPTER THREE: GEOLOGY

ASTRONOMY has given us an outline of the manner in which the sun, moon, and stars have evolved from a form of matter much lighter than the flimsiest cloud. Now we must turn to our earth to examine by the aid of geology some of its history. The word " geology " is from two Greek words—*ge*, earth, *logos*, science—and the subject embraces all that can be known or inferred of our world.

It is now generally admitted that, at a very early period, our globe was a molten mass—a thick liquid at a high temperature. As this mass swung in space, its surface cooled and solidified to form the crust of the earth. The " globe " (Fig. 48) is not exactly round, but like an orange with flattened ends—a fact that was discovered by Newton. If you place an orange on a table, the top will represent the North Pole and the bottom the South Pole; the straight line joining the two poles represents the *axis*, and a circle around the bulge of the orange the equator. The earth does not rest on anything; it swings in space and turns round on its axis once every twenty-four hours at a rate such that a man standing on the equator is travelling at over 1,000 miles an hour. The circumference of the earth is about 25,000 miles at the equator; its diameter in the same region is nearly 8,000 miles. The short bipolar diameter is some twenty-six miles less.

The solid crust of the earth is about fifty miles thick. Whether in its earlier stages this was smooth or rough is not known, but we do know that at one period the earth was an unfurnished world, devoid of stratified rocks, water, plants, and animals. The materials now composing this crust are rocks of mineral matter of various kinds, as granite, sandstone, coal, clay, chalk. Some are hard, others soft; but, geologically speaking, all are rocks. Some of them, such as sandstones and limestones, always occur in parallel layers termed strata (Latin: *stratum*, anything spread out), and are therefore known as stratified rocks. These may lie almost flat, as in *A* of Fig. 49; or they may slope at an angle, as in *B*; or again, they may be bent into arch-like folds, as in *C*. When the ingredients entering into the make-up of the stratified rocks are studied they are found to resemble those of pebbles, sand, or mud, which at the present time are being brought together and deposited by the water in our rivers, lakes, and oceans. The geologist, therefore, because the stratified rocks are formed through the action of water, calls them aqueous and sedimentary rocks (Latin: *aqua*, water; *sedimentum*, a settling).

You can see the order of arrangement of the sediments in Fig. 50; reading from the top, we have mud, sand, gravel.

Vast masses, even mountains, of rocks exist of quite a different character; such are the granites, basalts, etc. As these are irregular and have no layers, they are known as unstratified rocks. They have no regularity of position or of arrangement and often occur among the stratified rocks, which they pierce through or even overlie in broad, vast masses (Fig. 51, B). The lighter-coloured layers (A, B, C, in Fig. 49) are the stratified rocks, and among them the dark masses (Fig. 51, B) represent the unstratified. As these latter resemble in their composition and arrangement the material poured out by volcanoes, geologists ascribe them to the same agency—namely, the heat of the earth's interior—and call them igneous rocks

FIG. 48.—The Earth.

Our earth has a polar radius of 3,950 mi. and an equatorial radius of 3,963·34 mi. Its land area is $5{\cdot}747 \times 10^7$ sq. mi., and its ocean area $1{\cdot}395 \times 10^8$ sq. mi., the total surface area amounting to $1{\cdot}97 \times 10^8$ sq. mi. The highest land is Mt. Everest, 29,003 ft., the deepest abyss 34,219 ft. (Pacific). The mass of the earth is $6{\cdot}595 \times 10^{21}$ tons, and its mean sp. gr. 5·52 (water = 1·0) or 344·7 lb. per cu. ft. The mass of its atmosphere is $5{\cdot}1 \times 10^{15}$ tons and of its oceans $1{\cdot}3 \times 10^{18}$ tons or $2{\cdot}56 \times 10^{20}$ gall. The world's river discharge into the oceans is 6,500 cu. mi. annually, supplying them in the same period with $5 \times 10^9$ tons of mineral matter. The salts of the ocean amount to 38·0 lb. per 1,000 lb. of sea-water. The volume of the earth is $2{\cdot}52 \times 10^{11}$ cu. mi.; its mean orbital velocity is 18·5 mi. per sec. Its mean velocity of rotation is 0·289 mi., or 1,526 ft. per sec. The earth's mean distance from its offspring the moon, and from its parent, the sun, is, respectively, 238,854 mi. and 92,800,000 mi. (See also Figs. 19, 21, 26, 27, 29, 30, 31.)


FIG. 49.—Stratified Rocks.

(Latin: *ignis*, fire).[1] In Fig. 52 we see the Giants' Causeway, in Ireland, where once lava was poured out and, cooling under great lateral pressures, split into pentagonal and hexagonal columns, which in olden days were thought to be the work of giants and demons.

The stratified rocks alone contain fossils, and thus are of importance for our purpose. We have seen that they were formed principally through the agency of water. Had the early crust been subject to no modifying causes, it would have remained in its simple, bare, early condition; there would have been no change of surface, no succession of plants and animals, and no stratified rocks. But owing to the revolution, round the sun, of the earth and its rotation about its own slanting axis, and the revolution round the earth of the moon, there has been introduced a succession of modifying agencies—day, night, summer, winter, heat, cold, winds, rains, rivers, waves, currents, tides, frosts, and glaciers—and the consequent periodical rhythms in plant and animal life. Again, the interior of our globe, as we have just seen, is a vast reservoir of heat, the effect of which is seen in hot springs, geysers, volcanic eruptions, earthquakes, etc. By the

FIG. 50.—The Floor of a Lake after a Flood.

[1] The temperature of the earth increases one degree Fahr. for every 50 feet depth. This would give a temperature of 400,000° F. at the centre. But the rise in temperature is probably not maintained at this rate, so that the actual temperature at the centre is below this point, possibly but a quarter as much.

combined agencies of these forces ceaselessly operating within and around the earth, its crust is being continually altered, the old rocks crumbling away to sand while new ones arise.

All the known facts concerning the constitution, density, and elasticity of our globe are consistent with an interior composed of a mass of molten minerals. However, here we are dealing only with the crust of the earth, and this, we have seen, is exposed to so many powerful forces that it is never at rest. One result of these forces is the formation of a third kind of rock, the metamorphic, which is moulded under great heat and pressure out of stratified or unstratified rocks. Common slate is a good example of a sedimentary rock that has developed cleavage as a result of regional metamorphism.

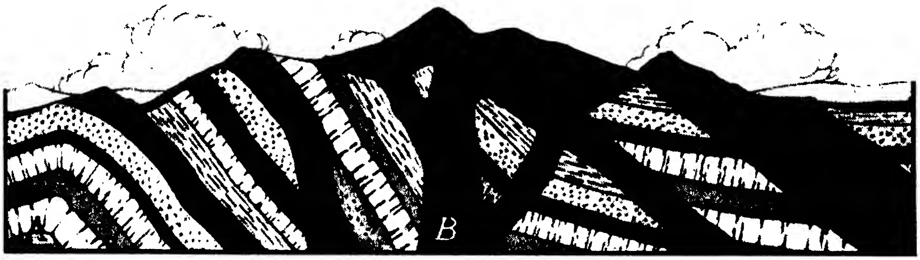
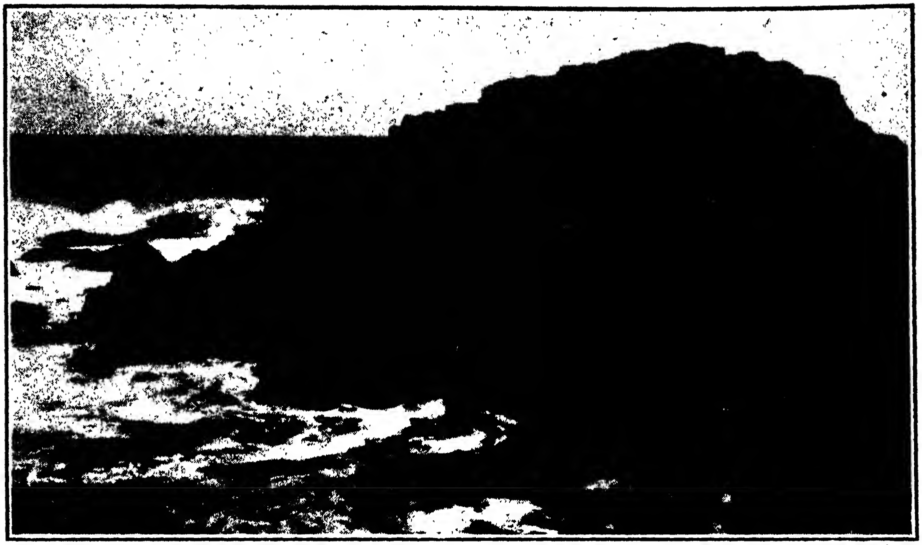



Fig. 51.—A, Stratified; B, Unstratified Rocks.

As far back as 1799 William Smith, at the age of twenty, noticed that the series of animal and plant fossils succeed one another in regular order, and that their type affords a means of identifying the strata. Fig. 53, showing the ideal " pillar of the rocks " of the earth's crust, is not drawn to scale and therefore does not convey an adequate idea of the vast depths of the pre-Cambrian formations. To correct this the thickness in feet and the age in millions of years of the strata are given. The thickness stated is the maximum known, and the ages quoted are based on evidence afforded by the radio-active minerals (thorianites, uranites, etc.) contained within certain of the rocks. The estimates are given on the authority of Dr. Arthur Holmes, Professor of Geology at the University of Durham. When Lord Kelvin gave a limit of 1,000 million years as the time during which the physical state of our globe might have permitted of life, his fellow-physicists were loth to allow geologists so much time for the evolution of animals and plants. The pendulum has now swung to the opposite extreme, and the modern physicists' grant of 1,500 million years as the span of life-potentiality more than justifies Kelvin's estimate.



Fox Photos

FIG. 52.—Basalt (the Giants' Causeway).

Surely, after this, we shall hear no more of the old difficulty, that there has not been sufficient time for the many species to arise.

Before entering into details we will learn the general characters of the fauna whose fossils figure in divisions in this pillar (Fig. 53). Beginning with the ancient rocks, the division above the lowest black line, we learn that they contain but the merest traces of a few classes of living things. Working our way upwards from the bottom of the pillar, we learn that the vast divisions of rocks called the *Primary* contain fossils belonging to genera and species usually distinct from those of the present day.

The *Secondary* era yields fossils, all of extinct types but more or less allied to recent forms.

The plants and animals represented in the *Tertiary* era belong partly to existing and partly to extinct species.

The *Quaternary*, Anthropozoic, or Recent, era comprises the formations still being deposited, and these contain, broadly speaking, the remains of plants and animals identical with those alive to-day.

To return to the bottom of the pillar, the rocks as far as the top of the Ordovician are characterized, for the most part, by small marine animals in shells, in a wide sense *Molluscs*. But in the Ordovician, armoured fishes begin to appear. Above the Ordovician comes the Silurian, which, with the next higher, or Devonian, division is known as the age of fishes. It

| ERA | EPOCH | DEPTH, IN THOUSANDS OF FEET: FOR EACH EPOCH | DEPTH, IN THOUSANDS OF FEET: SURFACE TO BOTTOM OF EPOCH | AGE IN MILLIONS OF YEARS: FOR EACH EPOCH | AGE IN MILLIONS OF YEARS: SURFACE TO BOTTOM OF EPOCH | IDEAL LAYERS OF STRATA | BEDS DEPOSITS ETC. | DOMINANT FAUNA AND FLORA |
|---|---|---|---|---|---|---|---|---|
| ANTHROPOZOIC | HOLOCENE | ·25 | ·25 | ·02 | ·02 | | PRESENT HISTORIC NEOLITHIC. | MAN |
| QUATERNARY | PLEISTOCENE | 3·75 | 4 | ·98 | 1 | | PALÆOLITHIC GLACIAL | |
| CAINOZOIC OR TERTIARY | PLIOCENE | 13 | 17 | 7 | 8 | | NORFOLK NORWICH AND LENHAM BEDS. | MAMMALS AND MODERN FLORAS |
| | MIOCENE | 14 | 31 | 12 | 20 | | TORTONIAN HELVETIAN LIMESTONES. | |
| | OLIGOCENE | 12 | 43 | 15 | 35 | | HEMSTEAD BEMBRIDGE OSBORNE | |
| | EOCENE | 20 | 63 | 25 | 60 | | BAGSHOT LUTETIAN ALUM BAY LONDON CLAY. | |
| MESOZOIC OR SECONDARY | CRETACEOUS | 44 | 107 | 50 | 110 | | MONTIAN CHALKS GREENSANDS WEALDEN PURBECK | REPTILES AND HIGHER FISHES |
| | JURASSIC | 8 | 115 | 30 | 140 | | PORTLAND CLAYS CALLOVIAN OOLITES CHELTENHAM LIAS, BLUE ETC | |
| | TRIASSIC | 17 | 132 | 40 | 180 | | LIAS, WHITE SANDSTONES | |
| PALÆOZOIC OR PRIMARY | PERMIAN | 12 | 144 | 25 | 205 | | LIMESTONES. RED SANDSTONE. | AMPHIBIANS LYCOPODS AND PRIMITIVE FISHES |
| | CARBONIFEROUS | 29 | 173 | 80 | 285 | | COAL MILLSTONE GRIT LIMESTONES. | |
| | DEVONIAN | 22 | 195 | 45 | 330 | | OLD RED SANDSTONES. | |
| | SILURIAN | 15 | 210 | 40 | 370 | | LUDLOW WENLOCK LLANDOVERY TARANNON. | |
| | ORDOVICIAN | 17 | 227 | 78 | 448 | | CARADOCIAN LLANDEILIAN ARENIGIAN | |
| | CAMBRIAN | 26 | 253 | 77 | 525 | | OLENEIDIAN PARADOXIAN OLENELLIAN. | HIGHER INVERTEBRATES |
| PROTEROZOIC | UPPER PRE-CAMBRIAN | 90* | 343* | 325 | 850 | | KEWEENAWAN ANIMIKIAN HURONIAN ALGOMIAN SUDBURIAN. | LOWER INVERTEBRATES |
| ARCHÆOZOIC | LOWER PRE-CAMBRIAN | 90* | 433* | 400 | 1250 | | LAURENTIAN GRENVILLE | UNICELLULAR PLANTS AND ANIMALS |
| AZOIC | | ? | ? | 1250 | 2500 | | IGNEOUS MOLTEN | COLLOIDS, WATERY SOLUTIONS OF SALTS AND GASES |
| | | | | | | | GASEOUS | VAPOURS AND GASES |

FIG. 53.—General Table of the Earth's Strata and Geological Time-Scale. (After *Arthur Dendy, F.R.S., Arthur Holmes, D.Sc., F.G.S.*, and "*British Museum Guide to Department of Geology and Palæontology.*")

* Uncertain, but depths are *at least* as stated.

would be difficult to over-rate the importance of these three periods, for they witnessed the origin of the first vertebrates (Ordovician), the rise of the lung-fishes, from which all terrestrial vertebrates have probably sprung (Silurian), the first amphibians (Devonian), and the first invasion of the land by vertebrates (Devonian).

The Carboniferous period marks the age when enormous plants flourished and coal-beds were formed. Here, too, are huge sharks and lung-fishes. This was the age of *Amphibians*, including the great scaled and " roof-headed " types from which the reptiles and mammals sprang.

The Permian shows the end of Trilobites; but fish are now plentiful and amphibians abound, also lizards of many kinds, as well as spiders, scorpions, centipedes, primitive insects, and snails. It was the harsh climate of these times, consequent on periodic glaciations, that compelled the primitive insects to develop those larval adaptations that enable them to tide over the cold spells in the resting conditions of *pupa* and *chrysalis*.

The next great division, the *Secondary* or Mesozoic, is known as the age of reptiles. Some of these grew to a huge size; others took on a bird-like form.

In the Triassic age the first mammal, a sort of duck-mole, appeared.

Reptiles were dominant in the Jurassic age, though many of them did not attain their zenith until the next or Cretaceous age. Primitive mammals were now abundant; in fact all the land vertebrates, as well as the higher fishes, were on the increase, although the archaic fishes, especially the sharks and rays, were on the down grade.

In the Cretaceous or chalk period the highest order of fishes (*Teleosts*), and wading birds *with teeth* adapted for holding fish, were coming into prominence. The great reptiles, some of which, such as Diplodocus, weighed twenty tons or more, were still dominant and had become highly specialized. Ichthyosaurs, Plesiosaurs, and Mosasaurs ruled the seas, the last even invading the abysses; Pterosaurs had conquered the air; and huge, fierce, carnivorous Dinosaurs lorded it over the land. Towards the close of the period, however, they all suddenly became extinct.

Passing to the *Tertiary* rocks we find that the vertebrates were essentially similar to those of the present day. All the existing sub-orders of fish were then present; but the greatest change occurred in land vertebrates, for mammals suddenly became the dominant type.

Most important of all, there arose, at the base of the lowest or *Eocene* division of the Tertiary group, two genera whose names, when translated, are the flesh-toothed (Creodonta) and the knuckle-jointed (Condylartha) —the ancestors of the Carnivors, Insectivors, and hoofed animals of the

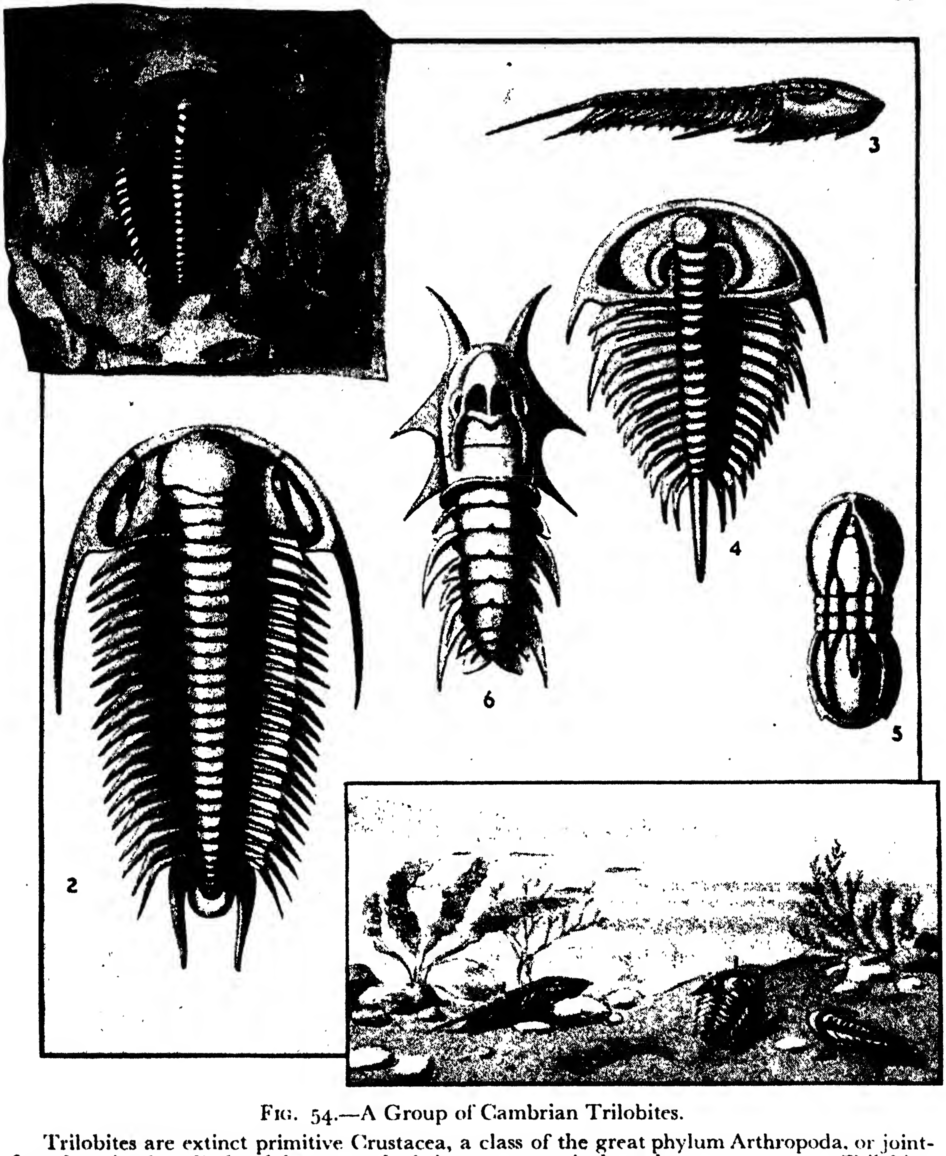



FIG. 54.—A Group of Cambrian Trilobites.

Trilobites are extinct primitive Crustacea, a class of the great phylum Arthropoda, or joint-footed animals. Crabs, lobsters and shrimps are typical modern crustaceans. Trilobites lived in the ooze of the ancient sea-bottom, attaining their dominance in the Cambrian, but not dying out until the Permian. Our common woodlouse, itself a crustacean, bears a striking resemblance to the trilobites. Trilobites arose out of still more primitive animals, the annelid worms, and in their turn they give origin to later water-breathing crustaceans and to at least two branches of air-breathing arthropods.

1. Olenus micrurus. 2. Paradoxides bohemicus. 3–4. Olenellus thompsoni. 5. Agnostus princeps. 6. Clenelloides.

present day. In the upper part of the *Eocene* occurred placental mammals, among which were the primitive horse (Eohippus), lemurs, and marmosets.

In the *Oligocene*, or next higher part of the Tertiary, there occur cats, also certain animals intermediate between dogs and bears, the early horses Meso- and Mio-Hippus, Mastodons, and, what is very significant from the point of view of man's origin, the first monkeys and apes.

In the third part of this division, the *Miocene*, the mammals, both in number and kind, reached their culmination. Browsers were succeeded by grazers, and both horses and elephants made great progress.

In the fourth or highest part of the *Pliocene* occur the order of cats to which our domestic cat belongs, antelopes, pigs, apes, and man-apes. It was in this period that man-ape became man.

We now reach our topmost division, the *Quaternary*. It is divided into the *Pleistocene*, or great glacial period, and the *Recent*. Towards the close of the preceding Tertiary period the climate became gradually colder, and with the beginning of the Quaternary there set in those periodic glaciations that spread over Northern Europe and North America. In Europe alone the ice is computed to have covered 770,000 square miles, and in places to have been 6,000 feet thick. On the Scottish mountains

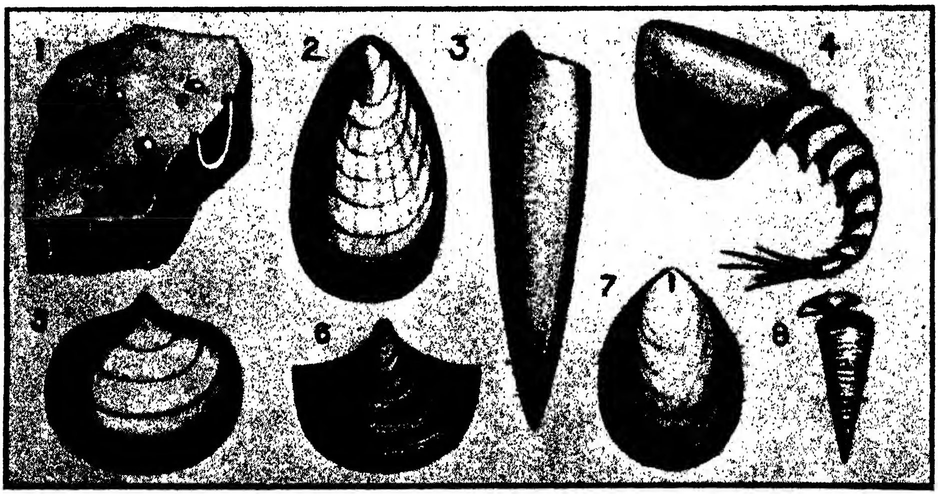



FIG. 55.—Other Cambrian Fossils.

1. Burrows of Arenicolites didymus. 2. Lingulella ferruginea. 3. Conularia homfrayi. (These fossils, probably of a kind of Palaeozoic worm, were often known as "thunderstones.") 4. Hymenocaris vermicauda. (The modern marine crustacean Nebalia is a closely related descendant of Hymenocaris; note the armour-plated head in the ancient form.) 5. Kutorgina cingulata. 6. Micromitra (Paterina) labradorica. 7. Lingulella Davisii. 8. Hyolithes (Theca) operculatus.

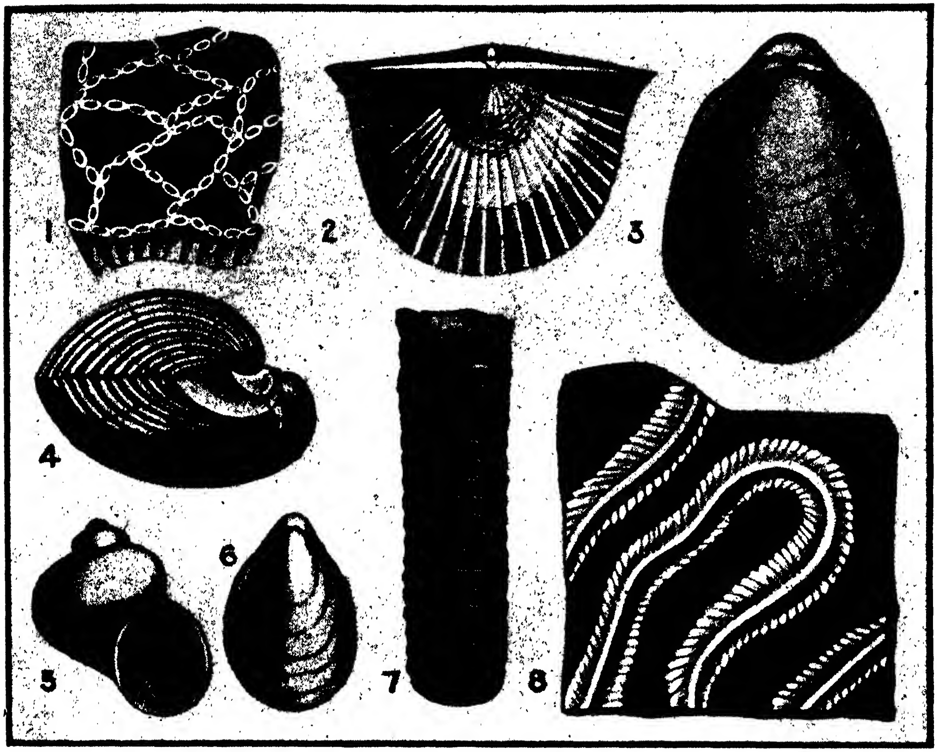



FIG. 56.—Upper Silurian Molluscs.

1. Halysites escharoides. 2. Strophomena antiquata. 3. Pentamerus oblongus. 4. Pentamerus Knightii. 5. Holopea Guelphensis. 6. Merista loevis. 7. Orthoceras ornatum. 8. Trail of Nereites Loomisii.

there are marks of the ice-sheet at heights of 3,000 feet and more. This enormous mass of moving ice overwhelmed the fauna of many districts, and so preserved for us relics by which we are able to reconstruct the long and interesting history of the earth's inhabitants, among whom were the sturdy men of the ice-age.

Geology is a science dealing with so many millions of years that the mind is baffled in trying to grasp the time involved. Low forms of living things that were little more than specks of jelly seldom left any record in solid rocks under a pressure of many tons; in most instances where fossils have been found they are the remains or impressions of animals that possessed shells, bones, or scaly coverings; and of these we invariably find the more evolved forms in the uppermost rocks, and the simpler and less evolved in the lower rocks. Thus, we have to trace the rocks up from the

bottom through layers representing millions of years before we meet with any *vertebrate*; and this, as we should expect, is a fish. We must then search through the higher rocks for further millions of years before we meet with a reptile, mammal, or bird.

The whole of the evidence of the rocks is in flat contradiction to the supposition that all animals, or even the same groups of animals, were made at the same time. The facts that races of animals and genera of plants have become extinct, that species of both which survive through long periods become so changed that they have to be classified as new species, are utterly opposed to the account of the creation of animals as given in Genesis.

### Archæan and Pre-Cambrian Rocks

In the rocks before the Cambrian period very few true fossils have been found. Heat and pressure have so metamorphosed the Cambrian rocks that impressions made by living things have for the most part been obliterated. "Indirect evidences of the long process of life evolution are found in the great accumulations of limestone and in the deposits of iron and graphite which are considered proofs of the existence of limestone-forming algæ, of iron-forming bacteria, and a variety of chlorophyll-bearing plants. *These evidences begin with the metamorphosed sedimentaries overlying the basal rocks of the crust of the primeval earth.*" (After *Osborn.*)

Working upwards once more from these Archæan formations to those of our own time, we will take a brief glance at some of the specimens we meet with at the various levels.

### Cambrian Division

We begin with small shell animals from the sea; and the point to emphasize is how slow is the appearance of animals which at all resemble those living around us now. Fig. 54 and Fig. 55 show the most abundant animals of this early period; they are all, you will note, small, low forms, enclosed in shells.

### Silurian Division

In the Silurian division the Trilobites continue, though some have changed their form. Fig. 56 shows other life of the period.

### Devonian Division

Fig. 57 is from the Devonian or old red sandstone rocks. It is a vertebrate, but it has no jaws, and in this and other ways is probably allied to the lampreys; it is, in fact, a fish in the making.

In Fig. 58 are shown some ancient fish bearing protective armour-plating. During this age fish were branching out in many directions, and forms resembling existing fishes were appearing. Sharks abounded, and Fig. 59 shows one of these ancient fishes. In Fig. 60 is a Crustacean, a member of a group that includes lobsters, crabs, cray-fish, shrimps, etc.

## Carboniferous Division

We have now reached the Carboniferous period, when coal was formed through the deposit of an enormous and abundant vegetation that then flourished. The small shell-covered marine animals continue, though under altered forms and as new species. Many orders of fish occur with more highly developed structures, but the new marvels of this period are the stegocephalian or roof-headed *Amphibians*. In Fig. 61 you see the skull of one of these.

## Permian Division

Fig. 62 is a good representation of the same amphibians as present in the Permian period. The utmost interest attaches to them, for from some of these animals came the reptiles which gave rise to mammals.

It is not to be supposed that these great divisions are marked off by some hard-and-fast line; the fauna of any one layer in a division merge with and closely resemble those of adjacent layers, but the fauna from layers that are well separated form distinct groups.

## Triassic Division

We now pass from the Primary division to the Secondary. The lowest group of rocks in this division is called *Triassic*. They contain the remains of those reptiles which gave origin to the mammals. Fig. 63 shows one of the Thero-

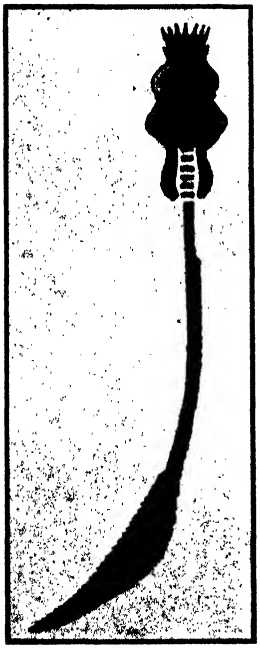


Fig. 57.—A Fish in the Making. (See also Figs. 58, 59, 87, 88, 89, 91, 92, 94, 95, 96, 100, 238, 239, 240, 241.)

This tadpole-like creature is known as *Palæospondylus Gunni*. The fossilized specimen was discovered in the Devonian Caithness flagstones. Traquain, the great ichthyologist, thought it was a cyclostome. The cyclostomata (round-mouthed) are a class possessing round sucking mouths and chitinous teeth. Sollas believed the remains to be those of a primitive amphibian. Yet another authority (G. Kerr) regards it as either a larval or an adult form of mudfish.

morpha or mammal-shaped reptiles. Note what a crude, raw specimen it is.

Fig. 64 shows the skull of a higher example of that shown in Fig. 63, and Fig. 65 represents the skull of a weasel-like reptile. The top drawing gives a side view; beneath are upper and lower views of the skull with a tooth lying between. The appearance of this skull shows that the animal was as cruel and fierce as any of our carnivorous mammals.

## Jurassic Division

The next division of the Secondary rocks is called the *Jurassic*; its reptiles are noted for their huge size. By now they had conquered the land (Dinosaurs), the air (Pterosaurs), and the sea (Ichthyosaurs and Plesiosaurs).

Brontosaurus (Fig. 66) attained a length of 66 feet and a weight of 38 tons, but recently remains of reptiles which probably measured as much as 150 feet in length have been discovered. Megalosaurus (Fig. 67) is another of the gigantic animals for which this period is famed; and Fig. 68 shows a flying reptile. Some of them were very formidable in appearance; for example, Allosaurus had a cavernous mouth with a battery of saw-like teeth, while its hands and feet terminated in the tearing talons of some mighty bird of prey. But in this period there was unostentatiously appearing a small, simple type of warm-blooded viviparous animal that was destined to

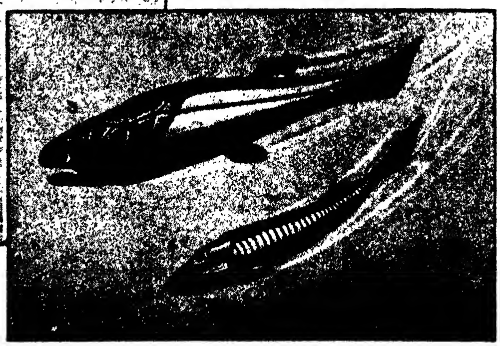



**Fig. 58.—Four Early Forms of Fish.**

**1. Pteraspis rostrata. 2. Pterichthys milleri. 3. Coccosteus decipiens. 4. Cephalaspis murchisoni.**

**These ancient fishes had the fore parts of their bodies armour-plated by means of bony plates. Their rise in life took place in the Ordovician of the early Palæozoic.**

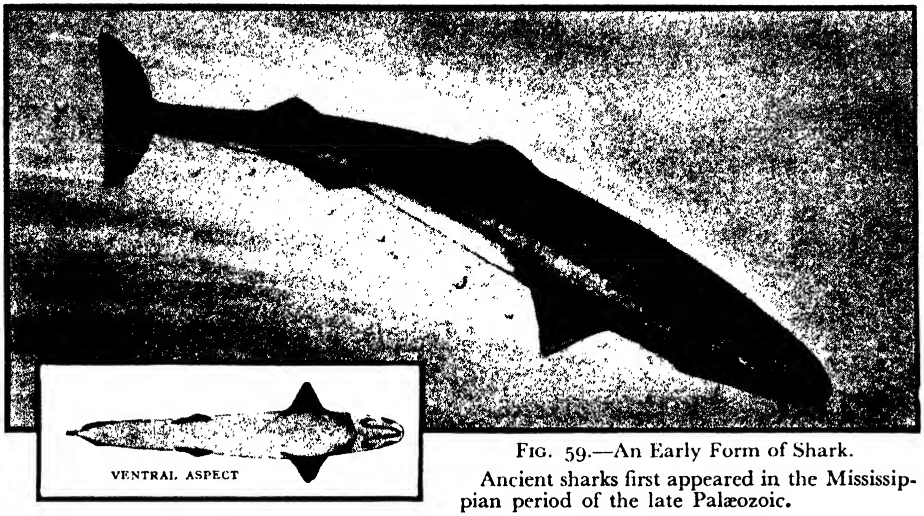



FIG. 59.—An Early Form of Shark.
Ancient sharks first appeared in the Mississippian period of the late Palæozoic.

change the whole living order of the world. This was the first mammal, and, if alive now, we should probably class it as a very primitive kind of duck-mole, closely related to the pouched animals, or marsupials. Birds with the tails and teeth of reptiles also appeared at this period.

### Cretaceous Division

The topmost division of these Secondary rocks is the great chalk age, called *Cretaceous*. This marks very little change from the preceding group.

Some of the great reptiles attained a zenith during this period and then rapidly disappeared. In America, about the middle of the Cretaceous, Nature, always red in tooth and claw, seems to have excelled herself in having brought forth the most fiendish and diabolical living engine of destruction the world has ever seen and, let us trust, ever will see. This monster was *Tyrannosaurus rex*, arch-enemy of the harmless, unarmoured, bird-footed (*Ornithopoda*) dinosaur *Trachodon*, whose one hobby in life was munching horse-tail rushes. In his *Parade of the Living* Professor J. H. Bradley sums up the character and appearance of this creature in a way that should make its petrified ears tingle: " *Tyrannosaurus* came forth, the supreme climax of a sanguinary race. He was death in a living body, the largest and most horrible beast of prey the earth has ever seen. Forty-seven feet of powerful flesh had been built into a body heavier than that of even the largest elephant. Standing on massive hind limbs that supported his entire weight, he towered twenty feet above the ground. His head was more than four feet long, three feet deep, and nearly

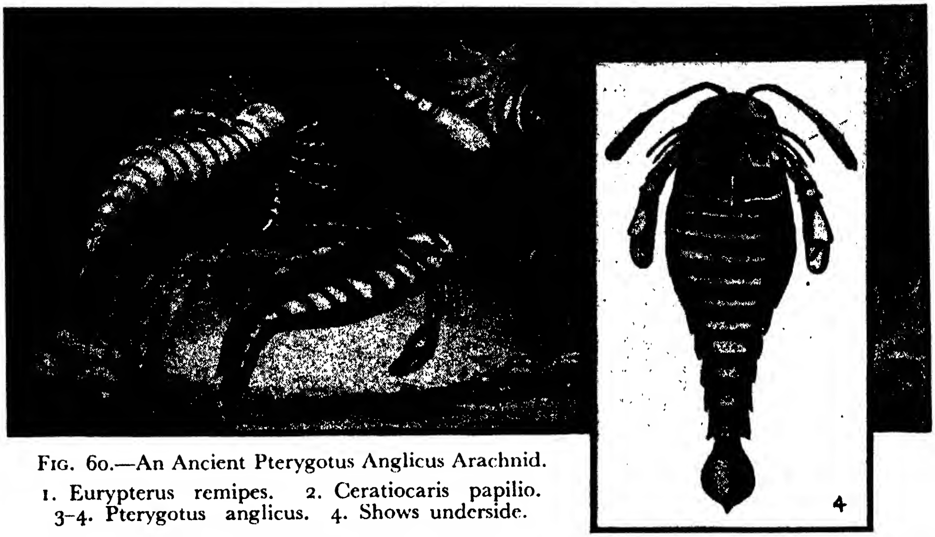



Fig. 60.—An Ancient Pterygotus Anglicus Arachnid.

1. Eurypterus remipes. 2. Ceratiocaris papilio. 3–4. Pterygotus anglicus. 4. Shows underside.

Above is depicted a giant Eurypterid, an ancient arachnid. The arachnida are a group of the Arthropoda, which includes spiders, scorpions, mites, king-crabs, and eurypterids. Pterygotus, from the old Red Devonian Sandstone, attained a length of six feet. The two broad, paddle-like appendages at the sides are powerful swimming-legs. It had two median ocelli close together at the top of the head, and one compound eye at each side of the front of the head.

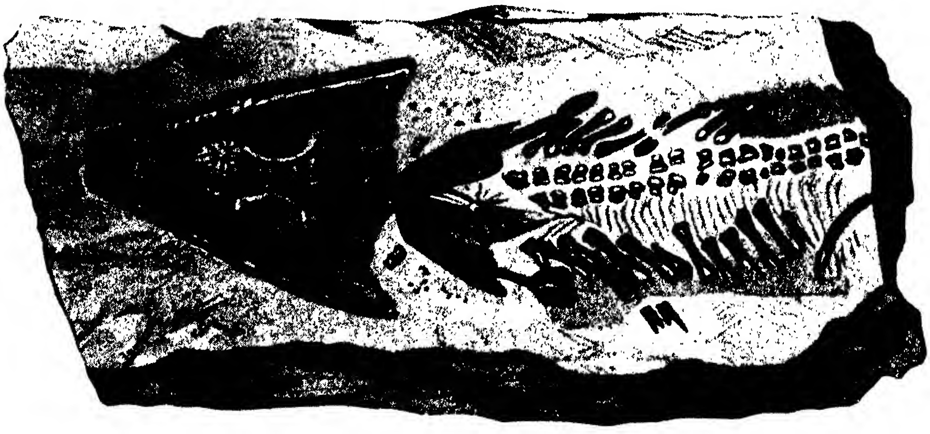


Fig. 61.—Archægosaurus.

Archægosaurus is an extinct amphibian of the sub-class *Stegocephala* (head-covered), which extended throughout the upper Devonian to the Triassic. These creatures' heads were protected by "armour-plating," and they probably had a functional pineal eye, since the skull is pierced above what would be the site of this organ in other animals known to possess it. The stegocephalia were small animals resembling crocodiles; a few attained a length of 8 feet.

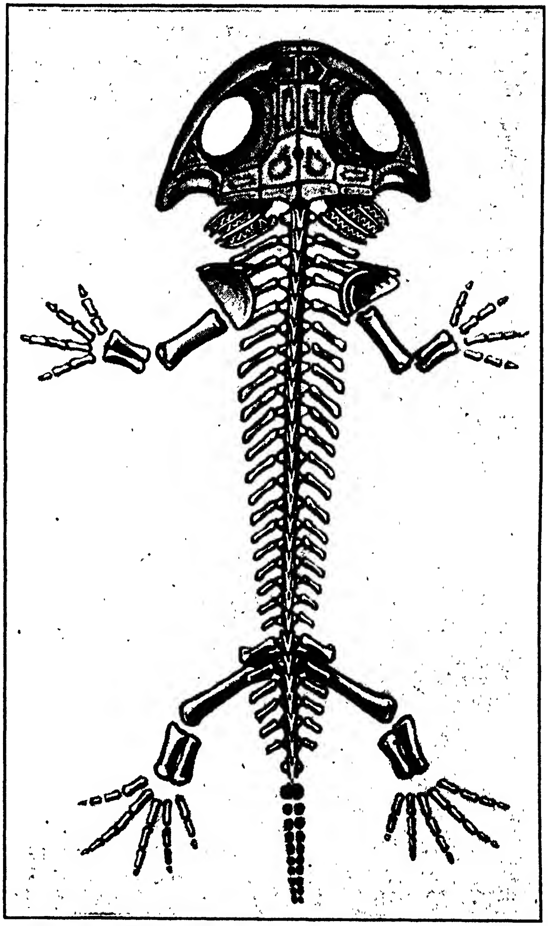
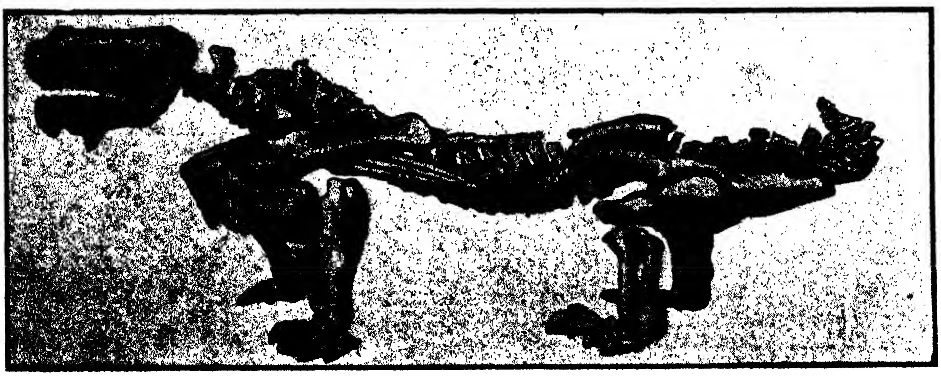


FIG. 62.—Branchiosaurus Amblystomus.

This is another stegocephalian from the Permian of Germany. The fossilized skeleton is probably that of an immature animal, since gill-arches that must have functioned as a water-breathing apparatus are present. The teeth of stegocephalians were conical, but one group of them had the enamel of their teeth complexly convoluted, and for this reason were called Labyrinthodonts. Stegocephalians were not transitional animals; the adults were fully developed amphibians. For the most part these creatures were small, weak-limbed, sluggish and crocodile-like in their gait. A few attained a length of nine feet.

FIG. 63 (below) (see also Fig. 244).—Pariasaurus Baini, from the Karoo, South Africa. (See Fig. 64.)

It belongs to the order Theromorpha (beast-like), a group foreshadowing the mammals. Related theromorphs were the pelycosaurs, which developed enormous bony outgrowths from their backbone which at times resembled, says Lull, the yard-arms of a square-rigged ship.



three feet wide. His jaws were set with daggers three to six inches long, and on his toes were claws as long as a man's hand. . . . For more than one hundred million years muscle was the measure of success, and by that measure *Tyrannosaurus* was easily king." But other colossal reptiles came on the scene which had evolved weapons and armour that were well able to keep at bay even such bloodthirsty fiends incarnate as

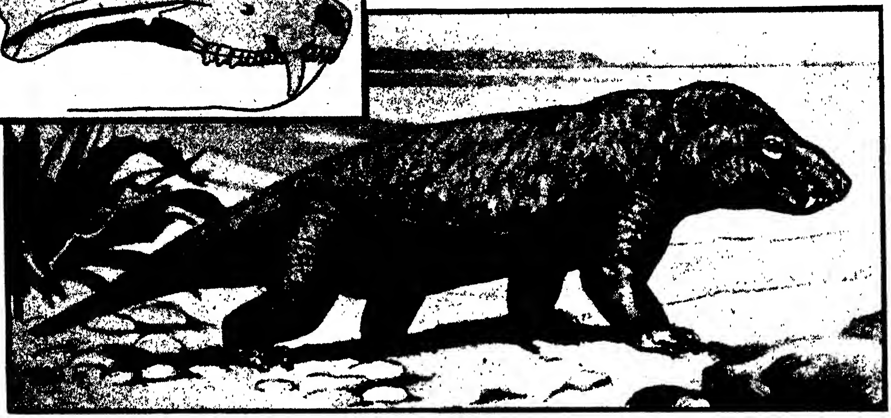


Fig. 64.—The Dog-jawed Reptile, Cynognathus.

Cynognathus belonged to a group of extinct lizard-like terrestrial animals known as Therapsids, which existed from the middle Permian to the Triassic. Like reptiles, they often possessed a well-marked pineal foramen; like mammals, they had teeth differentiated into incisors, canines, and molars—in fact, they exhibited a mixture of reptilian and mammalian characters. Cynognathus was unearthed in the Lower Trias. Pariasaurus, the skeleton of which we saw in Fig. 63, was probably not unlike Cynognathus in outward appearance.

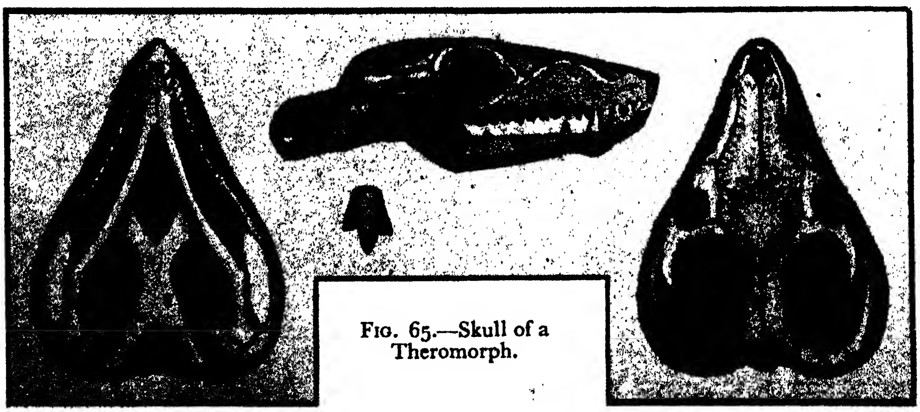


Fig. 65.—Skull of a Theromorph.

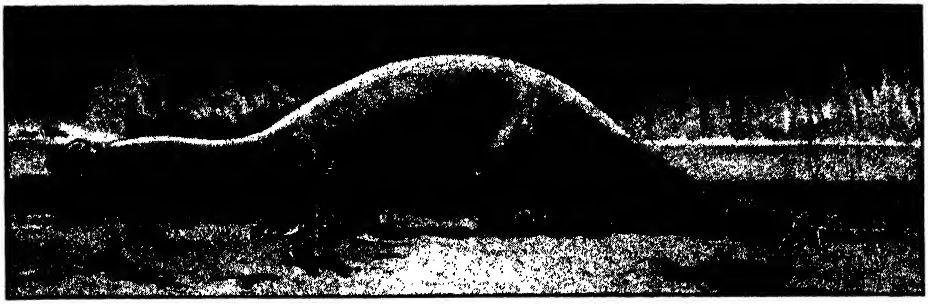
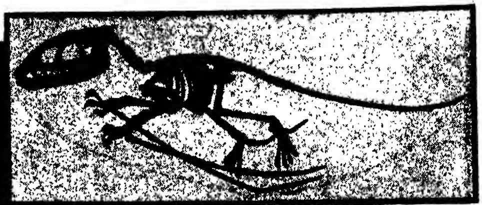


FIG. 66.—Brontosaurus. (See also Figs. 63, 65, 67, 68, 69, 108.)

A gigantic Sauropod (bird-footed) extinct reptile from the Late Mesozoic (Comanchian) of N. America. It was one of the first dinosaurs to become extinct, probably because of its huge body and tiny brain. It had a length of 66 feet and weighed about 38 tons, and laid eggs! One of the latter would contain the contents of about 160 hen's eggs. Brontosaurus was aquatic and quadrupedal, though when partially buoyed up by water it probably walked on its hind legs. Its joints were somewhat imperfect—a fact alone that points to a semi-aquatic life. Matthew has shown that a line drawn from shoulder to hip separates the lighter portion of the animal's frame from the weightier as though it represented the water-line.

FIG. 67.—Megalosaurus. (Gigantic extinct reptile.)

One of the dinosaurs (terrible reptiles) belonging to the suborder Theropoda (beast-footed). It flourished in Europe from the Jurassic to the Cretaceous. INSET: Skeleton of dinosaur in characteristic attitude on its two powerful hind-legs.



INSET: Skeleton of flying reptile. Note the elongated fourth finger.

FIG. 68.—Dimorphodon, a Flying Reptile. (See also Fig. 110.)

Dimorphodon was one of the pterodactyls (wing-fingered) or pterosaurs (winged reptiles). Its two fore-arm bones (radius and ulna) were of equal length; a very strong and thick fourth metarcarpal (hand-bone) bore an enormously elongated fourth finger, to which was attached a huge patagium, or membranous wing. The first, second, and third fingers were free, and ended in tearing and climbing talons. As in birds, the two bones of the arm (humerus) were perforated by a foramen that afforded communication between the cavity of the bone and respiratory organs, thus enhancing that pneumaticity favourable to flight in the air.

*Tyrannosaurus*. These were the stegosauria and ceratopsia. The former have been termed "the most ponderous animated citadels" in the world. Fig. 69 is certainly a very different type of dinosaurian reptile, and, though itself doomed to extinction, may have been one of the animals which were aiding the incipient mammals slowly but surely to oust from their overlordship of the American Continent the gigantic, beast-footed (Theropoda) dinosaurians. Many of these latter, possibly even Tyrannosaurus itself, it is thought, met their end through getting impaled upon the horns of Triceratops.

Figs. 70 and 71 are two of the half-reptile-half-bird animals of this period. They have points resembling the lizard, and also, as you see, teeth. Many primitive mammalian forms were now coming on to the stage, several of them small, pouched creatures; others were allied to the duck-mole; while yet others may have belonged to the order of insectivorous animals.

We pass now to the third great division of rocks—the *Tertiary*. Here a striking change in the fauna has been brought about by corresponding changes in the crust of the earth. A great, massive, uniform formation,

like the chalk which had been deposited in the sea, has given place to thin beds of sandy, shaly, or calcareous rocks. The large orders of huge reptiles have practically disappeared, and where the bed of the sea used to be are now millions of square miles of dry plains over which roam animals such as the world had never seen before. Hence this period is called the New-life or Cainozöic. Crocodiles, sea-snakes, tortoises, and turtles are now the sole survivors of a great class that once ruled the world.

## Eocene Division

In the lowest group of this division, the *Eocene*, we find the dominant animals are mammals.

Coryphodon (Fig. 72) was an animal rather like the modern tapir, while Hyracotherium (Fig. 72), the most ancient known equine of the Old World, had a shape intermediate between the hog and the Hyrax. Tinoceras (Fig. 73) belongs to a group remarkable for its tiny brains yet massive heads. These animals were as big as elephants, had the habits and stupidity of rhinoceroses, and bore three *pairs* of horns—two on the snout, two on the forehead, and one on each cheek.

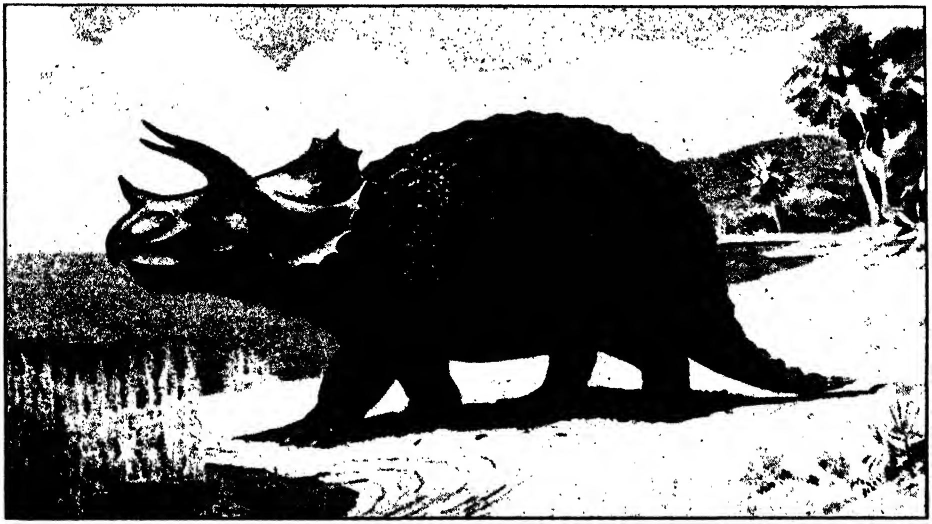


Fig. 69.—A huge armoured sluggish-footed three-horned dinosaurian reptile, Triceratops.

It belongs to the suborder *Ceratopsia* (horned), and was found in the N. American Cretaceous. It somewhat resembled a rhinoceros in general build; it was not a mammal, but belonged to the lower grade, the reptiles. Its length was about 25 feet, its skull alone accounting for about a third of this, a fact necessitated by its having to support the three horns, as well as a ponderous bony frill at the hinder end of it. The mouth was furnished with a large cutting turtle-like beak.

FIG. 70.—Hesperornis Regalis. (See also Figs. 71, 112, 163.)

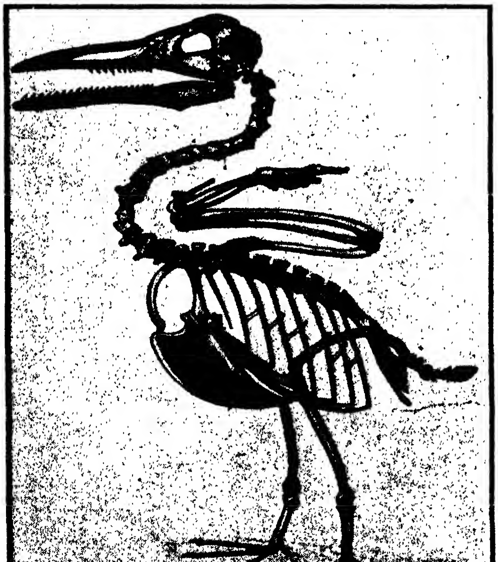


FIG. 71.—Ichthyornis Victor (restored).

Hesperornis, and its cousin Ichthyornis (shown in Fig. 71), belonged to the subclass of extinct birds called Odontognathæ (tooth-jawed). They also had bi-concave vertebræ. Hesperornis was a diving bird much resembling our Great Divers. Ichthyornis was more gull-like. The skeletons of both these toothed birds are preserved in Yale University Museum.

Not only are insectivorous animals found in the Eocene, but also several small animals of the lemur type, such as Adapis (Fig. 74), the earliest representatives of the Primates.

## OLIGOCENE DIVISION

The *Oligocene* plays but a subordinate part in England, being only in evidence in parts of Devonshire and Hampshire. Elsewhere, however, the period

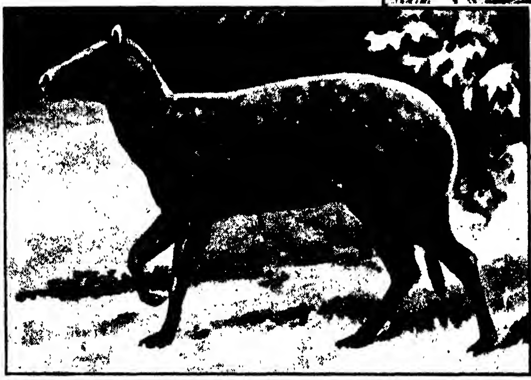


FIG. 72.—Hyracotherium (below), the most primitive equine known, belonged to the Family Equidæ. It had four functional digits in each fore-foot (manus). It was discovered in the London Clay of the Eocene, while Eohippus, a N. American contemporary, was unearthed from the Wasatch division of the same geological period.

As the premolar teeth of Hyracotherium are of a somewhat simpler type than those of Eohippus, the former is regarded as structurally the more primitive animal of the two.

Coryphodon (above) varied in size from a tapir, to which it bore a great resemblance (note the horse-like prehensile upper lip), to an ox. It was a swamp-dwelling creature.

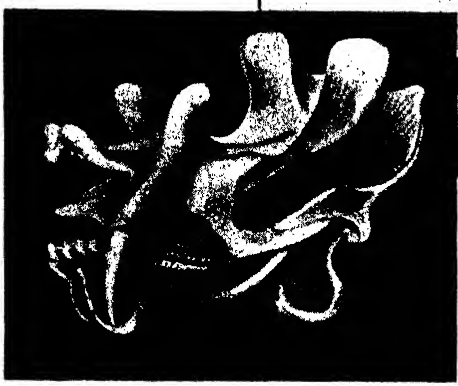


FIG. 73.—Tinoceras, a Huge Six-horned, Two-tusked Mammal of the Eocene, the Last of its Race.

The brain was remarkably small for so immense a creature. But for its head, it was very elephant-like, and stood about 7 feet high. Its massive skull (left) carried three pairs of horns, one pair 8 or 9 inches in length. Its canine teeth were greatly developed into backward-curving tusks. Tinoceras and its near relative Dinoceras, or Uintatherium, belonged to an archaic Order, the Amblypoda, related to the Ungulates, or Hoofed Mammals.

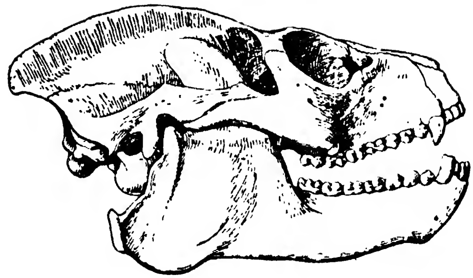


Fig. 74.—Skull of Adapis, a primitive type of lemur. W. D. Matthew regards certain early Insectivora at the dawn of the Eocene, in the early Tertiary, as our distant ancestors. They gave origin, probably, to generalized lemurs that appeared in both the Old and New Worlds. They soon became extinct on the American Continent, but in the Old World they worked south and entered Madagascar while it was still a part of the mainland. When this became an island, these primitive lemurs evolved into the lemurs proper, and flourished to such an extent that Madagascar now contains some thirty-five different species.

swayed considerably the course of Evolution. An increasing aridity of climate (that culminated in the Miocene) and a general uplifting of the dry land entailed the replacement of the tropical and sub-tropical forests by deciduous trees, and of marshlands, lakes, and streams by vast prairies. Leaf-eating animals were cut out in the struggle for existence by the grass-eaters; while the Primates, which received such a good "send off" in the Eocene, met with a severe rebuff through winter curtailing their hitherto continuous fruit food supplies. Speaking generally, the period was one of mammalian advance, especially of the earlier forms of the camel, horse,

Fig. 75.—Arsinoitherium, of lower Oligocene, a rhinoceros-like animal but with the two horns placed laterally. Discovered by H. J. L. Beadnell, F.G.S., of the Geological Survey of Egypt in the Fayum Desert, N. Africa. Moeritherium and the remains of the ancestors of modern elephants (Palæomastodon beadnelli) were also found in this desert.

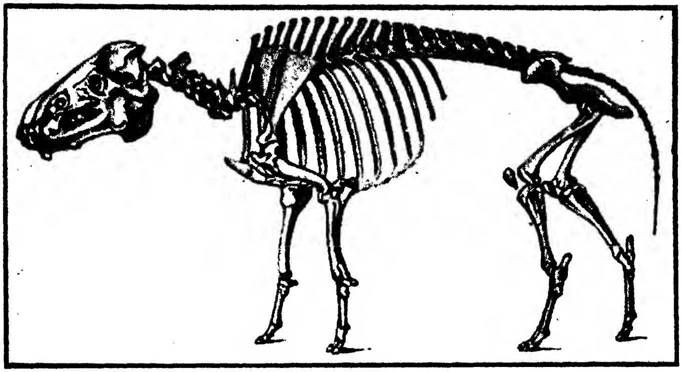


Fig. 76.—Elotherium.

An extinct artiodactyl or even-toed hoofed ungulate. They were camel-like creatures belonging to the section Tylopode.

elephant, and rhinoceros. One of the last (*Arsinoitherium*) is shown in Fig. 75.

Elotherium (Fig. 76) is a large, camel-like animal, which, you should note, had learnt to walk on its toes. It is found in the Miocene of Europe and North America. The Mastodon (Fig. 77) has now appeared, but not until the next period does its cousin, the Elephant proper, come on the

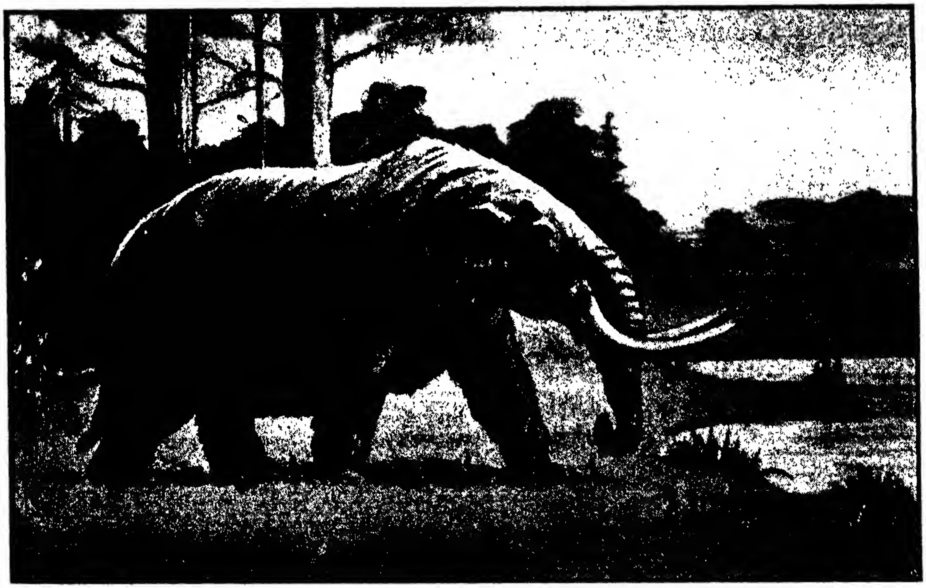


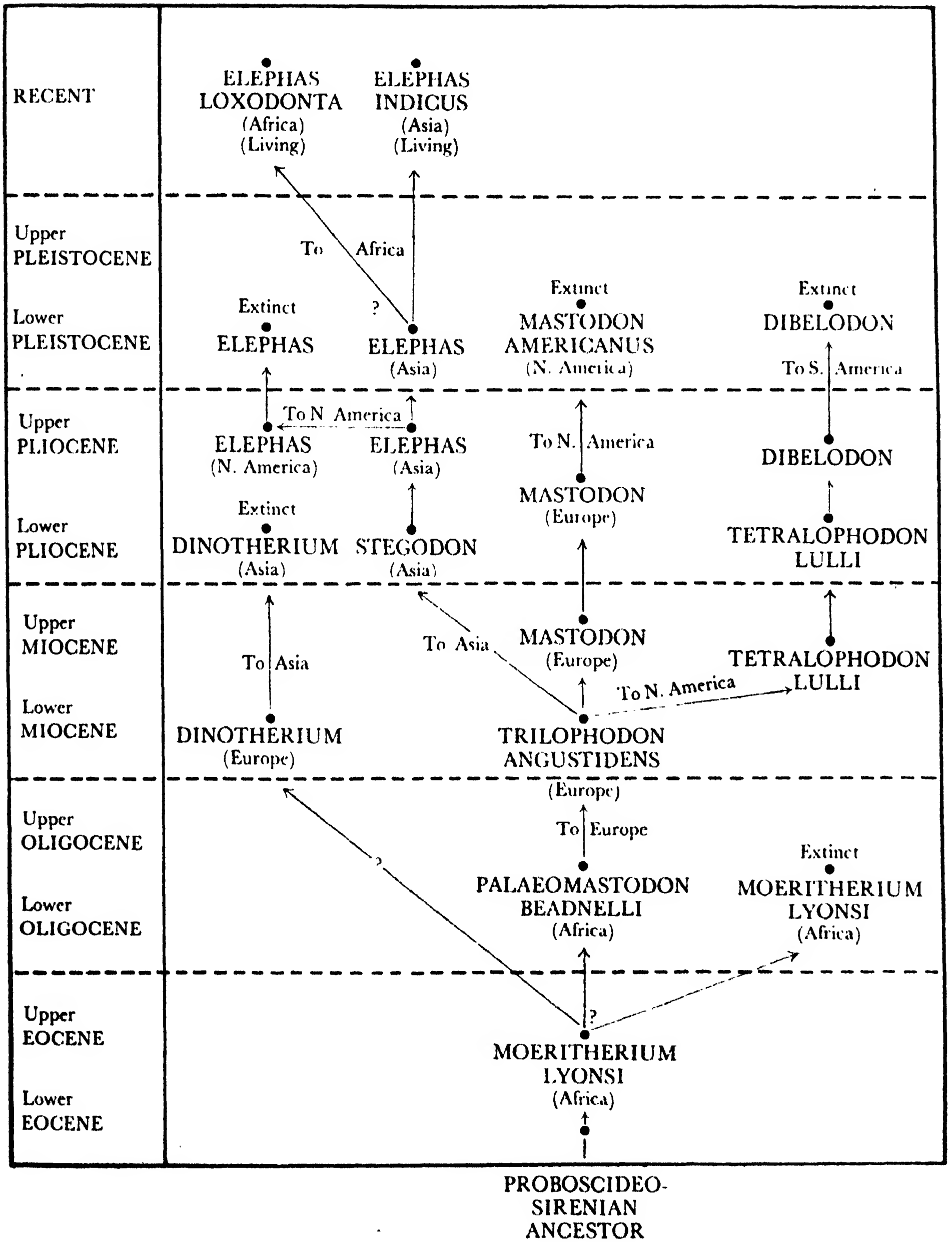
Fig. 77.—Mastodon.

It stood 7 to 9 feet high, about the size of our Indian elephant, but more thick-set. The name means "breast-toothed," because of the shape of the teeth. The upper tusks sometimes exceeded 9 feet in length.

scene. Both these creatures were offspring of the Miocene *Trilophodon*, grandchildren, so to speak, of the Oligocene *Palæomastodon*, and great-grandchildren of the little Eocene *Moeritherium*. The phylogeny or genealogical tree of the Elephant has been worked out by zoologists with extraordinary accuracy and detail, of which the following is a short sketch.

The genealogical tree of elephants probably started in the sea or in the shore-waters in some sea-cow- or manatee-like animal in lower Eocene days.[1] We shall see later on that the whale in all probability started in a pig-like terrestrial animal that gradually took to living in the sea. This "proboscideo-Sirenian ancestor," as Lull describes it, evolved in the upper Eocene and lower Oligocene into a little swamp-dwelling creature, about 3½ feet high, called Moeritherium (beast of Moeris). Its remains, together with those of Palæomastodons, were discovered by H. J. L. Beadnell in fairly close proximity near the site of the ancient Lake Moeris, about 60 miles S.W. of Cairo. Moeritherium was just beginning to evolve the tusks and trunk so characteristic of elephants. In the middle Oligocene Moeritherium Mocritherium gave rise to and was replaced by Palæomastodon in the direct elephant line. It became extinct in the mid-Oligocene, but not before one of its descendants had migrated to Europe and evolved into the Miocene Dinotherium (terrible beast). This creature had downward-pointing tusks and a well-developed trunk. Nature disapproved of it, however, and after trying a fresh habitat in Asia it became extinct in the Pliocene. Its remains have been found in Germany, Rumania, and India. Palæomastodon of the African and Asiatic Oligocene increased in size, then migrated to Europe and evolved, in the Miocene, into Trilophodon, a creature nearly the size of the Indian elephant. Its great feature was a very long lower jaw, bearing relatively straight tusks. Trilophodon was a great wanderer, and gave origin to three distinct branches of descendants. Migrating to N. America, it gave origin to Tetralophodon (four crests), so called because its middle molar teeth bore this number of crests. In the middle Pliocene it became replaced by its descendant Dibelodon (two darts), so called because of its long forwardly projecting, dagger-like upper-jaw tusks. This descendant spread down to S. America, and then disappeared from the stage of life. The second Trilophodon branch evolved, in the upper Miocene, into the Mastodons (breast tooth), called thus because the middle molar teeth have become simpler in appearance.

[1] Other sources of origin suggested are the S. American Noto-ungulata, as well as the Hyracoidea.




FAMILY TREE OF THE ELEPHANT

They attained a stature of 9 feet, and in the Pliocene spread from Europe to N. America to become extinct in the Pleistocene. The third Trilophodon branch migrated to Asia, giving rise, in the lower Pliocene, to Stegodon (cover), a sort of half-way stage between mastodons and elephants. From Stegodon, in the upper Pliocene, was evolved the first true elephant. One descendant of this animal migrated to N. America in the upper Pliocene, and later became extinct in the Pleistocene. The second elephant branch had as its descendants the modern elephants of S. and Central Africa as well as those which remained in Asia, spreading to India, Ceylon, Burmah, Assam, Siam, Cochin China, Sumatra, and Borneo. The African elephant is smaller, but has larger ears than the Indian; its ivory is of a finer quality, and it is much less tameable. The schematic diagram of the evolution of elephants will be helpful to the reader.

The wonderful flesh-toothed animals (Creodonta), ancient Carnivors, appear for the last time in the Miocene. The middle Miocene is remarkable for a series of genera intermediate between dogs and bears, and also for *true apes*.

Fig. 78.—Hipparion.

A three-toed semi-desert horse of the Miocene and Pliocene. *H. whitneyi* was discovered in S. Dakota; other Hipparions were unearthed in Nebraska and Colorado. *H. gracilis* was found in the lower Pliocene, near Athens. It stood 44 in. or 11 hands high. *H. whitneyi* was a hand less in stature. The modern horse first appears in the upper Pliocene beds of Europe, Asia and North America. Its feet are one-toed, but splint bones represent the ancient second and fourth digits; it is a descendant of Hipparion, a close relation of Hipparcon. Inset: Foot of Hipparion. Note the splint bones bear functional hoofed pettitoes.

## Pliocene Division

We next come to the uppermost group of rocks in the Tertiary division, called the *Pliocene*. By this time the mastodon is widespread, and towards the end of the period the true elephant appears. Typical pigs have now replaced the pig-like forms.

Hipparion (Fig. 78) is one of the ancestral horses (though a cul-de-sac branch), which appeared and became abundant in the Miocene (only, however, to disappear in the Pliocene); but species of the true horse were also present. (See Fig. 13, page 10).

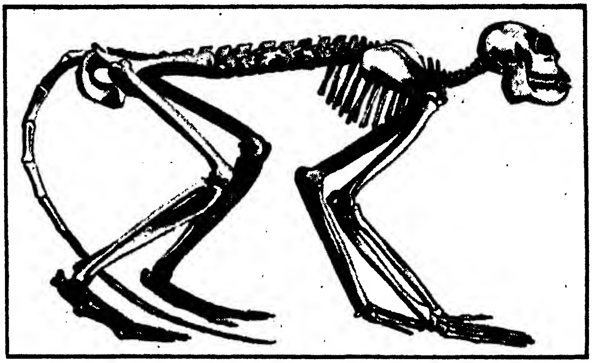


Fig. 79.—Mesopithecus. (Middle or half-way pithecus.) A long-tailed Pliocene ape from the site of Athens. The sacred Indian apes are modern examples of *Pithecus*.

## Pleistocene Division

We have now looked at the series of animals from early Cambrian times to the beginning of the great ice-age, as the *Pleistocene* period is often called.

True apes, which as we saw were already present in the Miocene of Europe, are now plentiful. Most European fossil apes can be referred to the family Cercopithecidæ, which includes all those now living in the Old World, except the gibbons, orangs, chimpanzees, and gorillas that together form the Simiidæ. The oldest fragments found of apes are the jaws and teeth of a comparatively large specimen from the middle Miocene of Tuscany. Fragmentary remains of apes are known from the Pliocene and Pleistocene of India, the most interesting being typical portions of the dentition of baboons (Cynocephalus), which are now restricted in their range to Africa and Arabia. Fig. 79 depicts the skeleton of Mesopithecus, a Pliocene ape unearthed at Athens. Other Pliocene apes have been disinterred at Montpellier (Macacus), and in France, Italy, and Asia (Semnopithecus).

The oldest known traces of a man-like skeleton are an imperfect roof of a skull, three teeth, and a thigh-bone, found, together with the remains of Pliocene mammals, near Trinil, Java, by Dubois in 1891. This creature,

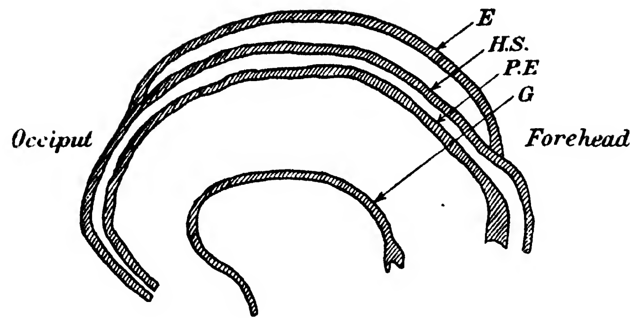



FIG. 80.—Outlines of skulls of the gibbon ape (*G.*). *Pithecanthropus erectus*, the Ape-man (*P.E.*), *Homo Sinanthropus*, Peking Man (*H.S.*), and a modern European (*E.*). (Modified from *Keith.*)

a humanoid representative of a side-branch of the true human stem culminating in present-day man, was named *Pithecanthropus erectus*, for it walked on two legs, like man. Keith and Elliot Smith are agreed that the part of the brain corresponding to that which in ourselves governs speech, though small, was sufficiently developed to allow of a primitive kind of talking. There is no doubt but that Pithecanthropus represented a form intermediate between man and the anthropoid apes. That is to say, could we trace back human beings to their common ancestral stock in the Pliocene, and the gorilla, chimpanzee and orang to their common stock at the same period of time, we should find Pithecanthropus linking them laterally as, so to speak, first cousins. But we should have to pass back to the Oligocene, or even Eocene, days before we should see a creature that represented the forebears of all existing men and apes and Pithecanthropus. Pithecanthropus was 5 feet 7 inches high, as compared with 5 feet 8 inches for the average European. The teeth of Pithecanthropus are much more human-like than those of the modern gibbon, but are nevertheless ape-like. It is known, however, that Pithecanthropus had already acquired the human method of mastication. It lived over 500,000 years ago either in the upper Pliocene or lower Pleistocene. Its lips and front teeth projected farther forward than those of Neanderthal man, and in general features the latter stood midway between modern

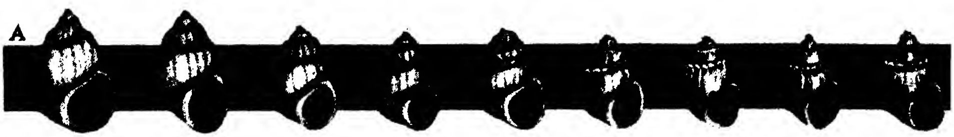



FIG. 81.—A series of varieties of a fresh-water snail, Paludina.

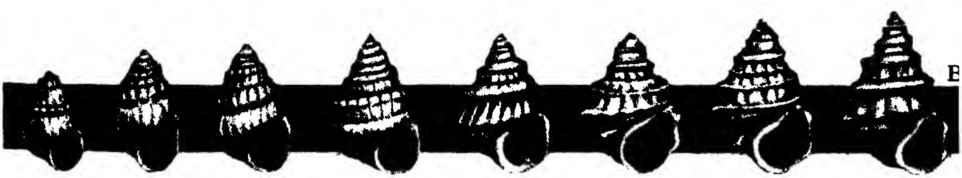
These fossilized fresh-water snails were found in parallel rows of successive deposits of the lower Pliocene of W. Glavonia. Each snail so closely resembles that in the immediate subjacent layer (of the deposit) as to be only with difficulty distinguishable from it, yet differs so greatly from a snail in widely separated deposits that zoologists have not hesitated to place representatives

man and Pithecanthropus. "The oldest human skeletons of which the geological age can be determined with certainty are two from the cavern of Spy, near Namur, in Belgium. These were found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite which had never been disturbed. They are essentially human in every respect. They represent a race small but powerfully built. The forehead is low, the supra-orbital ridges are very prominent, and the chin is remarkably retreating. The leg cannot have been quite upright in walking. This type is known as the *Neanderthal race*, other similar fragments having been found in 1857 in a cavern in the Neanderthal between Düsseldorf and Elberfeld, Germany" (*Woodward*). New human remains are found every few years, and some of these are held to be possibly even earlier than the Java ape-man. The Piltdown skull (Eoanthropus, the Dawn-man) is about 400,000 years old. Many others besides the above-mentioned are now known, and their general relationship to living races of mankind on the one hand, and to living and extinct apes on the other, as well as their estimated age, may be gathered from the genealogical tree on page 15 and on page 246.

FIG. 82.—Sir Charles Lyell (1797–1875). One of the greatest pioneer geologists.

Fig. 80 shows in outline the skull of Pithecanthropus compared with those of a gibbon ape, Peking Man, and a modern European.

We may fitly close this chapter with an example that sustains the doctrine of Evolution in an unmistakable manner. The remarkable series of shells of a fresh-water mollusc of the Tertiary age, shown in Fig. 81, exhibit almost insensible gradations; so much so, that, while the difference between any two adjacent specimens is scarcely discernible, that between



**of the extremes in different species, the simpler and earlier types as *P. Neumayri*, the more evolved and later types as *P. hœrnesi*. Here, indeed, we have the origin of species depicted as though on a cinema screen. Other transitional series have been obtained for the fresh-water mollusc, *Planorbis*.**

extremes is so marked that the shells might excusably be considered to belong to distinct species; indeed, before the discovery of the numerous connecting links they were so regarded. It is easy, from such a series as this, to imagine how, by continued derivation and modification, new species of animals and plants have arisen. The illustration depicts the whole " origin of species " at a glance.

From such an illustration some idea may be formed of what constitutes the present evidence in support of Evolution, and what that evidence will be when further links have been collected. The warning words of Dean Inge—" Those who take refuge in gaps will, sooner or later, find the gaps closing in upon them "—are proving true; many of the great gaps which existed have been filled up, while those that remain are being filled up. The Evolutionist watches the process in calm assurance, for every discovery but adds further proof of the truth of his doctrines; *not one throws the least doubt on Evolution.*

Sir Charles Lyell was perhaps the most eminent geologist alive when Darwin brought out *The Origin of Species.* Lyell had prepared the way for Darwin by showing in his *Principles of Geology* that there were none of those breaks called " catastrophes." But though Lyell and Lamarck between them had killed Cuvier's " catastrophic theory," still the former was not able at first to accept Darwin's explanation of the origin of species. At sixty-two years of age Lyell was still weighing the evidence; but at long last, in 1867, when he brought out the tenth edition of his *Principles of Geology*, he proclaimed that he accepted Evolution as true.

Such testimony from such a man, after eight years of the most cautious inquiry, at the ripe age at which culminated a career devoted to the study of the crust of the earth and its fossils, produced a sensational effect, for Wilberforce, the Bishop of Oxford, had relied especially upon Lyell to crush Darwin!

# CHAPTER FOUR: ZOOLOGY (AMŒBA, FISH, REPTILE, MAMMAL)

BEFORE evolution of any organism can take place there must be an environment more or less favourable to it. All organisms do not necessarily evolve in a straightforward manner to something higher and better; some take a zigzag course, others remain stationary, and yet others, after a brief forward advance, go back. While *all* living things are related one to the other, it is not true that every form of high plant or animal has come through *every* plant or animal *inferior* to it. Two brothers are closely related in virtue of the fact that each had the same parents, which biologically means that the fertilized egg-cell that gave rise to the father as well as that from which the mother arose, each contained a common ancestral representative of both. In each of those germ-cells the two brothers were identifiable as a single entity. Again, two cousins are less closely related than two brothers, because the germ-cells in which each was represented as a single entity were one or more generations farther back. Oak trees do not come from rose trees, but, if you could trace them far enough back, you would find some tree or shrub that was the ancestor of both. Some animals have developed on a main line, while others—for example, birds—have developed on a side line; but, though mammals and birds have come *from* reptiles, neither has come *through* the other.

If we look at the animal world as we find it in fossils and living forms, we shall learn that they are all one large family of near and distant relations. We will begin with one of the lowest forms of animal life.

The amœba (Fig. 83) is found in the water of ponds and ditches. It is one cell, complete in itself, but so small that it is only visible through a lens. It has no organs nor parts, no limbs nor mouth; in the resting phase it is spherical, in the active phase it is constantly changing its shape—in fact, its name is derived from the Greek word for *change*. It grows fast, and when it becomes so large that the surface can no longer take in enough food for the " inner man," it undergoes fission—that is, it simply tears itself into two. This fission is based on a well-known principle in physics—viz., that in an enlarging sphere the surface increases as the square of the radius, while the mass, or content, increases as the cube of the radius.

Consequently when, in the growing amœba, the interior begins to get starved through failure of the surface to pass in enough food, it splits into two, thus once more restoring a favourable relation between the surface and the inside.

The next step in evolution was that the cells, instead of separating after division, clung together. The protozoa became the metazoa or many-celled animals. The very small animals in Fig. 84 have been greatly magnified, and they show clearly how, after dividing and redividing, cells remain attached to one another and so form a many-celled animal. Number 9 shows the full-grown animal, and you can trace its growth from the single cell (1) to the multi-cellular gastræad stage (8). All living things, including man, grow in this way.

Animals that have no bones, or internal bony skeleton, are known as Invertebrates—*i.e.*, having no vertebræ or backbone. They are divided into many families—worms, snails, flies, etc. We are chiefly concerned at this point with the worm-like class, for in these animals was developed a tube inside the outer tube—hence their group-name, the Cœlomata, or hollow-bodied animals. Very soon the inner tube—probably because it was more sheltered and better fed—tended to grow longer than the outer one, so had to bend on itself, and this bending process continuing for millions of years eventually resulted in the many-looped intestines of higher animals. The earth-worm is a land animal in which we find a well-marked hollow body and a distinct blood system. It has a mouth at one end and a vent at the other, but being an invertebrate it possesses no bones.

FIG. 83.—Amœba Proteus in its Active Condition.

When at rest it has a spherical shape. A hundred of them side by side would measure an inch. The arm-like bodies are the pseudopodia. The white blood-corpuscles of our blood closely resemble in appearance and habits the amœba. It is an animal that never dies, except by accident. When "tired of life" it just divides into two offspring amœbæ.

We have now to look for the origin of the backbone. This took place in animals that lived in the water. Let us take a glance at Balanoglossus, the Acorn-worm (Fig. 85), a humble creature that burrows in the sand of the sea-shores between high- and low-tide marks. It is the most primitive member of the very large class of vertebrates, or backboned animals. Three features unite all this class: one is the structure

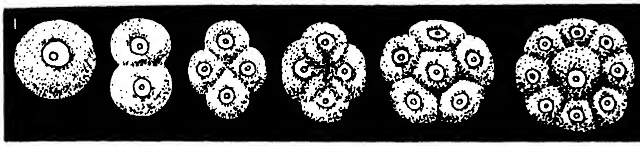
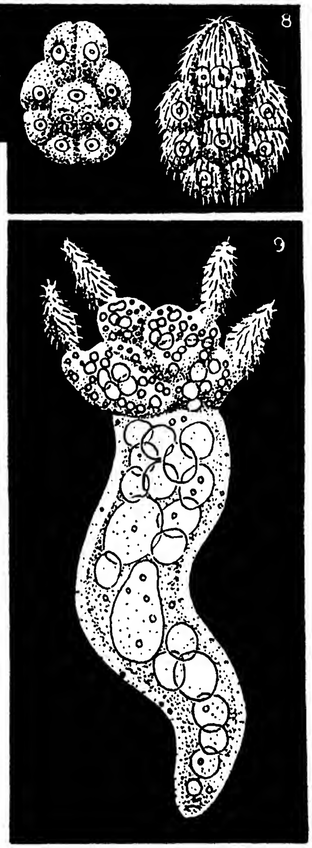




FIG. 84.—Modern Gastrula-like Animals, or Gastræads.

1–9. Gastrulation stages of *Conocyema* from (1) the protozoal to (9) the mature gastræad form.

A gastrula is a developmental stage in the growth of the embryo of most higher animals. The single cell or fertilized ovum, representing the starting-point of growth, divides and redivides until there results a solid, mulberry-like ball of cells, the *Morula*. This then becomes hollowed out in its central regions to form the *Blastula*. Next, the blastula becomes pushed in, or invaginated, at one side and the central cavity gets into communication with the exterior at one point by means of an aperture called the *Blastopore*, which represents the ancient mouth through which food was admitted to the central cavity, now called the *Archenteron*, and through which waste products were thrown out; the archenteron was, in fact, the ancient primitive gut.

called the *notochord*, a gristly rod running along the back; a second is the gill-slit openings in the front part of the food tube or alimentary canal, through which openings, or "gills," breathing is effected; and a third feature is the presence of a nervous system which commences as a strip of sensitive skin cells along the back that, becoming rolled into a tube, ultimately forms the *spinal cord* and nerve canal. These three characteristics will enable you to determine whether an animal is a vertebrate or not. In Fig. 85 the gill-slits are marked 5; the "collar" is marked 2, and in this is a short notochord, which projects into the "proboscis," marked 1. The mouth (7) is situated between the proboscis and collar. In this collar is also found a primitive nervous system consisting of a small nerve-mass and nerve-ring that send respectively nerves forward into the proboscis and backwards along the body. Consequently we are entitled to place this worm among the vertebrates.

Another member near the bottom of the vertebrate stem is the Sea-squirt, one of the Tunicates or Ascidians.

The full-grown animal is egg-shaped and three to four inches long (4, Fig. 86); it shows scarcely any trace of its vertebrate relationship. It is unable to move about and lives fixed to some support at the bottom of the

sea. It has an 8-lobed mouth through which sea-water is constantly drawn and then as constantly expelled through the atrial orifice. When "irritated" it squirts water out through both apertures, a habit that has given it its name of sea-squirt. In the three left-hand animals in Fig. 86 it will be seen how alike are the larvæ or tadpoles of the frog and sea-squirt. In each of these larvæ there exists a notochord. This is shown in section in No. 3 of Fig. 86 as the faint, short line running through the tail, below the black nerve-chord that extends throughout the whole length of the body to terminate in front in an enlargement that is the forerunner of the brain of higher vertebrates.

A third remarkable animal near the bottom of the vertebrates is the Lancelet, or Amphioxus (Fig. 87), a word meaning "pointed at both ends." This marvellous animal is found in the sandy shallows of the sea. It is from one to two inches long, has no "head" in the ordinary acceptance of the term, is nearly transparent, and possesses a stiffening notochord running the length of its body.

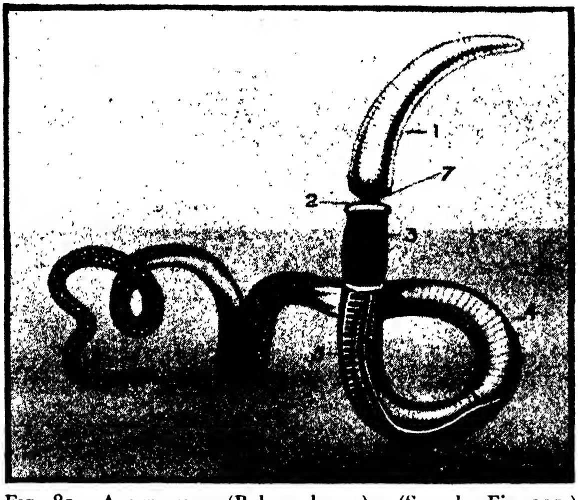



FIG. 85.—Acorn-worm (Balanoglossus). (See also Fig. 235.)

1. Proboscis. 2. Collar. 3. Operculum. 4. Reproductive zone. 5. Gill slits. 6. Anus. 7. Mouth.

The Balanoglossus is a primitive chordate animal, a forerunner, or close relation to the forerunner, of the vertebrates. The creatures vary in length from an inch to as long as six feet; they are brightly coloured and smell like iodoform. The adults are blind, but in some kinds the larvæ possess two eyespots. A nerve-cord runs down the back, connected by a nerve-ring with a network of nerves on its ventral aspect. The notochord is made of *chitin*, a material that stiffens the "shell" of crabs, etc., and it is situated inside the proboscis.

The acorn-worm, the sea-squirt, and the lancelet are probably three surviving representatives of many ancestral forms from one or other of which fish may have arisen. All land vertebrates, including, of course, ourselves, have undoubtedly evolved from some form of fish. Fig. 88 shows the jointed bones, or vertebræ, of a backbone, in this case a human one.

Let us take a look at some of the fishes, the lowest group of true vertebrates, so that we may have some idea of the vast variety of these animals.

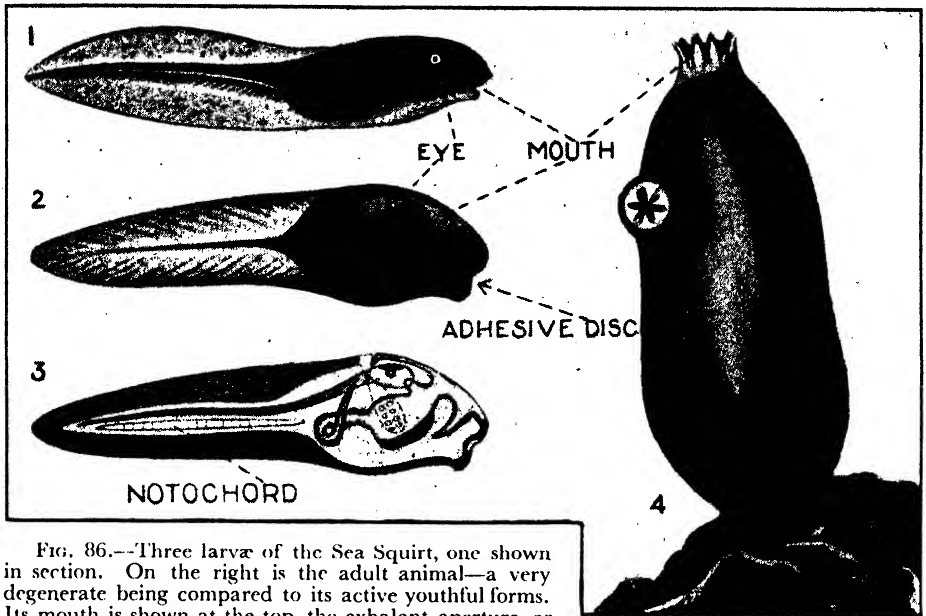



FIG. 86.—Three larvæ of the Sea Squirt, one shown in section. On the right is the adult animal—a very degenerate being compared to its active youthful forms. Its mouth is shown at the top, the exhalant aperture, or atriopore, on the side.

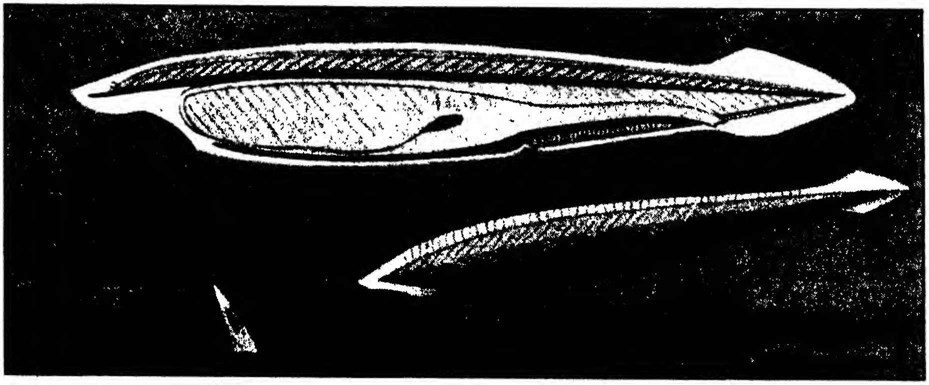


FIG. 87.—The lancelet, Branchiostoma, or *Amphioxus lanceolatum*, so called because it is pointed at each end. It has no brain proper, but a dorsal nerve-cord lies above the notochord, well shown in the top figure as a black line running from end to end. These circumstances place it in the phylum *chordata* and subphylum *acrania*. The creature is about 1½ to 2 inches long, and lives in the sand at the bottom of the sea at a depth of 2 fathoms, its head protruding as it feeds on diatoms and other tiny organisms. See the lowest of the three figures.

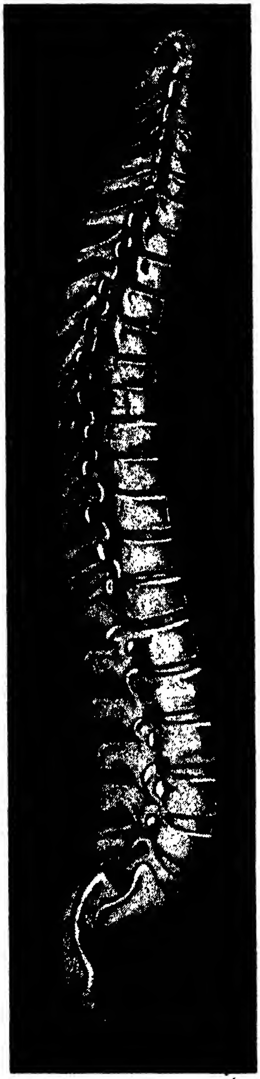


Fig. 88.—Vertebræ of the Human Backbone. The human vertebral column, or backbone, is a composite mechanism exquisitely adapted to an upright bipedal position, and hence is a much more specialized structure than that of a fish. Nevertheless, its first representation in the early stages of the human embryo is the simple gristly rod known as the notochord, which runs along the dorsal wall of the gut. The notochord does *not* develop into the backbone any more than the scaffolding grows into the chimney-stack.

Fig. 89 shows the Lamprey, a very low type of fish with a head scarcely marked off from the body. The lamprey belongs to the class Cyclostomata, or round-mouthed fishes. You may see in the lower of the two figures the round sucker by which the animal attaches itself to objects. These low, round-mouthed, jawless fishes, with a nose that is a mere sac, are put in a division by themselves to mark them off from the higher fishes which possess jaws.

The class Pisces (true fishes) is characterized by fins. The paired fins, from which have been evolved the four limbs of terrestrial vertebrates, are probably derived from the splitting up of two originally continuous lateral flaps.

Fishes are divided into three sub-classes: Elasmobranchii, Dipnoi, and Teleostomi.

The common ancestors of all the higher fishes were probably primitive shark-like types (*Elasmobranchs*).

Sub-class 1, the Elasmobranchs, contains Sharks (Fig. 90), Dog-fish (Fig. 91), Skates or Rays (Fig. 92), and the Holocephali (Fig. 93).

All the members of this old family exhibit a primitive stage of evolution, and, in common with the round-mouthed fishes, their skeleton consists chiefly of gristle or *cartilage*; hence they are also known as the cartilaginous fishes.

The Holocephali—that is, complete-headed—are now represented by five families that include the *Chimæridæ* (Fig. 93).

Sub-class 2, the Dipnoi, Dipneusts or double-breathers, sometimes called lung-fish, has only three living species: the Burnett salmon (Neo-Ceratodus), the Lung-fish (Protopterus), and Lepidosiren (Figs. 94 and 95).

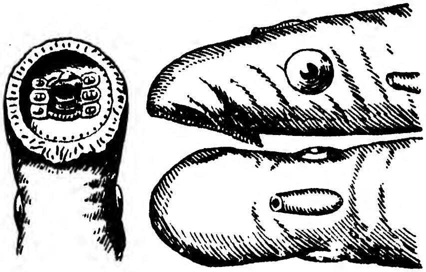


FIG. 89.—Head of a Lamprey, and (right) a Group of Lampreys.

The lamprey belongs to a primitive group of fishes, the Cyclostomes—round-mouthed, jawless, sucking creatures. They are chordates. Their primitive nature is shown thus: (1) the possession of non-medullated nerves throughout the body; (2) the alimentary canal is ciliated as in invertebrates; (3) whole skeleton is cartilaginous; (4) possession of a persistent unsegmented notochord; (5) a suctorial mouth for attaching themselves to stones, but with which they may adhere to higher fishes and draw nourishment from them; (6) possession of vestigial parietal and pineal eyes. There are three British species: (1) the sea-lamprey, 3½ ft.; (2) the river lamprey, 3 ft.; (3) the brook lamprey, a few inches long. Lampreys are true vertebrates, though of a primitive kind for they have no jaws, and what teeth they possess are chitinous (horny).

The Dipneusts breathe not only in the water, by means of gills like ordinary fishes, but also in the air, by means of *a lung or lungs*, and in consequence their blood-circulation differs from that of ordinary fishes. Neo-Ceratodus of Queensland has one lung, while both Protopterus of certain Central African rivers and lakes, and Lepidosiren of the Amazon, possess two lungs. All land animals have probably descended from some ancestral member, either of the Dipneusts or of a similar group such as the Crossopterygii, of which Polypterus of the Nile (Fig. 96) is a good example.

Sub-class 3, the Teleostomi, or perfect-mouthed fishes, is divided into two sub-orders:—

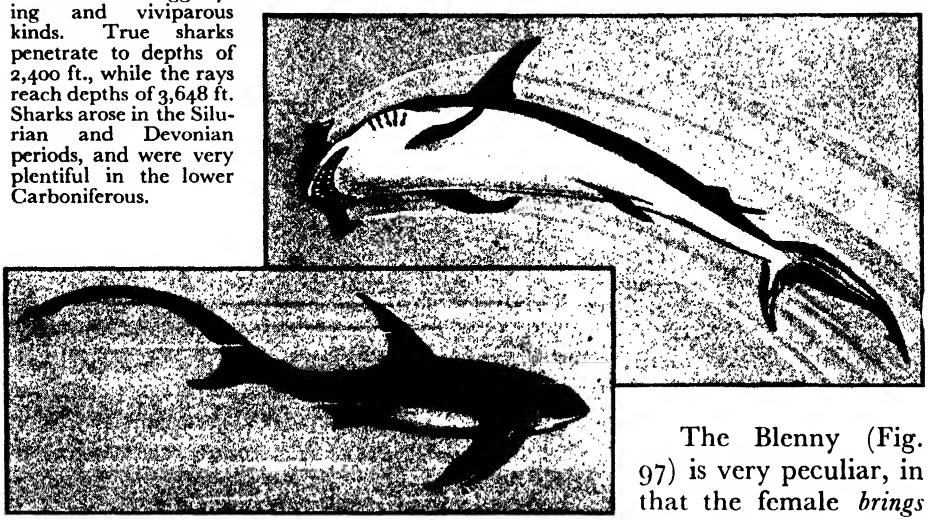
*a. The Crossopterygii* (the fringe-finned). There are only two living genera of this sub-order, Polypterus (Fig. 96) and Calamoichthys, which inhabit the rivers of Africa. In these fishes the air-bladder is occasionally used as a lung.

*b. The Actinopterygii.* This sub-order is divided into the Ganoids and Teleosts. The Ganoids figured very conspicuously in the past, the

original stock arising in the Silurian and flourishing in the lower Carboniferous periods. From the ancient true Ganoids (as distinct from the lobe-finned Ganoids) arose the Sturgeons, Garpikes, Bowfins, and the huge group of Teleosts, which includes most of our best-known fishes, such as the salmon, pike, herring, sole, perch, etc. There are perhaps ten thousand species in this division.

FIG. 90.—Hammer-headed Shark and (below) Thresher Shark.

Fishes may be divided into two great groups, the gristly or cartilaginous, and the bony. The sharks and rays belong to the former group. Their size varies from a foot, as in the case of the dog-fish of our British coast, to 40 or 50 ft. in the case of tropical man-eating sharks. Sharks include egg-laying and viviparous kinds. True sharks penetrate to depths of 2,400 ft., while the rays reach depths of 3,648 ft. Sharks arose in the Silurian and Devonian periods, and were very plentiful in the lower Carboniferous.



The Blenny (Fig. 97) is very peculiar, in that the female *brings forth the young alive*, while the male constructs a nest in which the brood are lodged. The male of the uncouth-looking Lumpsucker, shown in the same figure, is also a good father, for he not only carefully guards the eggs, but allows the young to cling to his body with their suckers.

Male sea-horses and pipe-fish (Fig. 98) place the fertilized eggs of the female in a pouch on their abdomen inside which the young are hatched out.

The climbing perch of India (Fig. 99) wanders about on land, and has been known to climb low trees by means of the spines on its gill-covers and ventral fins. It has an accessory breathing organ in connection with the branchial arches. Fig. 100 shows a fish the name of which means "one who can see all round." Periophthalmus runs about actively over the mud-flats, and climbs up the roots and stems of mangrove trees in the estuaries of the Indian and Pacific Oceans. Its movements over the land

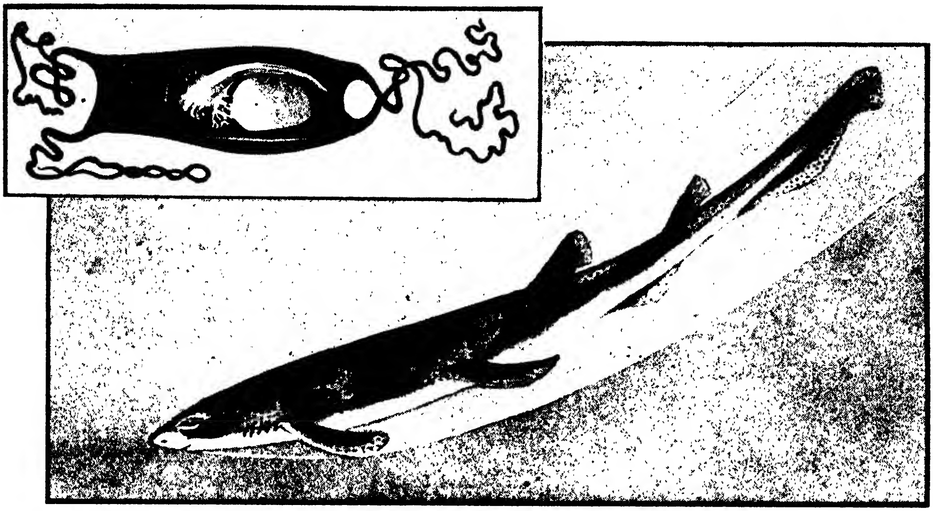


FIG. 91.—Mature Dog-fish.

(Above) An egg-case with its anchoring filaments (that automatically wind round a stalk of sea-weed) showing, within, an embryo dog-fish with its nourishing yolk-sac attached.

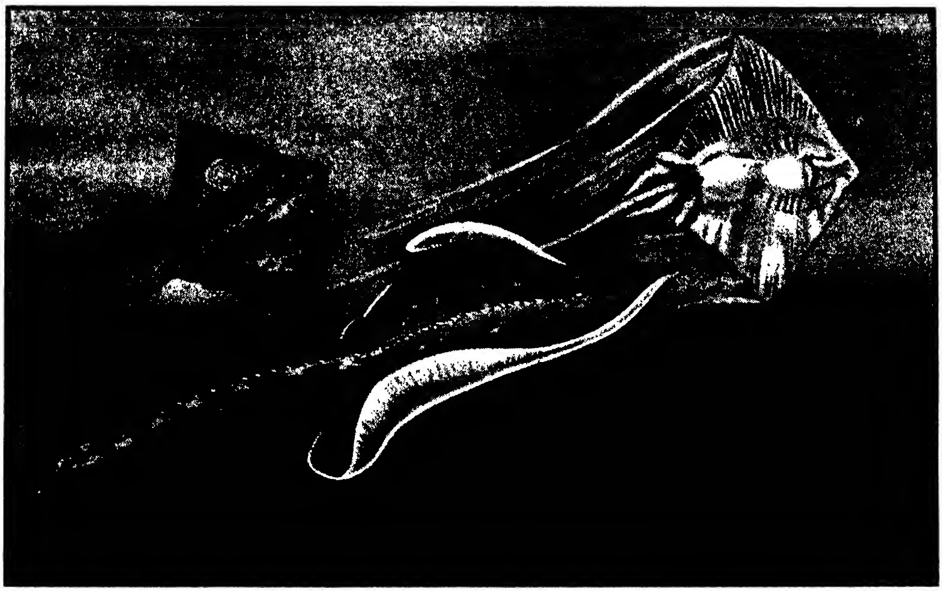


FIG. 92.—Skate or Ray.

The Ray is a true shark, as shown by the position of the mouth on its under surface. In ordinary sharks there are, as a rule, seven gill-clefts (*e.g. Hettanchus*). In skates there are five, four being the number in ordinary fishes (Teleosts).

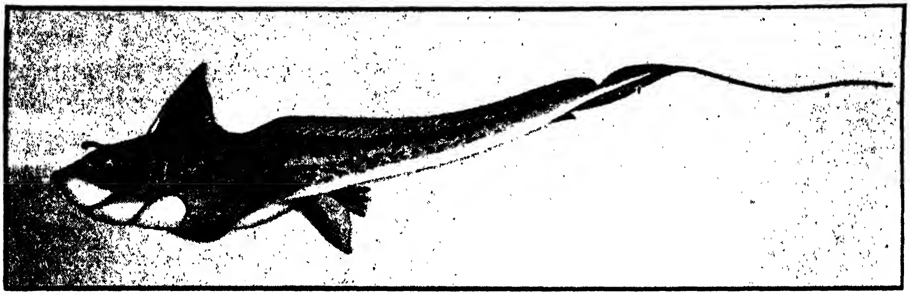


FIG. 93.—Rabbit-fish, Sea-cat, or Chimæra.

Its habitat is the northern seas. The skin of the adult Chimæra, as of other Holocephali, is naked, but that of the young contains a few scales. Some varieties of Chimæra are deep-sea dwellers and live at depths of 1,300 fathoms. Large eyes, in fishes, generally mean a dark habitat. The rod on the head is an accessory clasper; other claspers are represented by the hinder fins. Fossil Chimæras (*Ptychodus*) have been found in the Devonian; the chimæroid *Callorhynchus* in the Cretaceous; *Chimæropsis* in the Mesozoic.

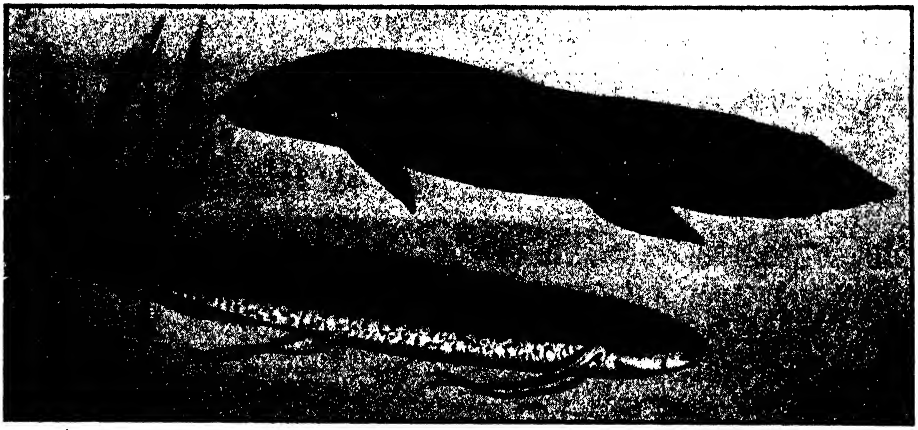


FIG. 94.—The Burnett Salmon (*Neoceratodus*), and (below) the Lung-fish (*Protopterus*).

*Neoceratodus*, or *Epiceratodus forsteri*, represents a very ancient type of fish. It dates from Mesozoic days, as *Ceratodus*. It is a real living fossil. The present fish lives in Australian rivers. It is one of the lung-fish, or Dipnoi, and although it cannot live for long out of the water, it can survive in thick stagnant water that kills ordinary fish, coming frequently to the surface and taking in great gulps of air with a grunting noise. It is also known as the Burnett salmon, or Barramunda. Length, 6 feet. Its air-bladder is single.

***Protopterus annectans.*** An African Lung-Fish from Senegal, Gambia, White Nile, Lake Tanganyika, and Zambesi.

It burrows into mud in dry season, living at the bottom of a tunnel, encapsuled in dry mucus and breathing air into its lungs. It is carnivorous, sometimes cannibalistic. Attains a length of 6 feet, but usually is about 3 feet long. It swims by its tail, using its slender fins for " walking " about the bottom of the river. Its air-bladder is double, and therefore more nearly approaches the paired lung of land animals. It has the primitive feature of a citrated intestine. *Protopterus* is another persistent ancient type—a true living fossil.

FIG. 95.—Lepidosiren.

Lepidosiren, the Amazon mudfish or lung-fish, attains a length of 4 feet. Its air-bladder is double. When the swamps in which it dwells dry up, it constructs a burrow, which it closes with a perforated clay plug, living at the bottom and breathing in air through the apertures in the stopper. It uses its hind-fins in bipedal fashion, forcing its way through the dense water-weeds and breathing air at the surface. It is known to the natives as the Lolach. Fossil forms are not known. In diet it is omnivorous.

give one a good idea as to *how fins developed* into terrestrial limbs. Fig. 101 shows the flying-fish with its large pectoral fins which sustain it in gliding flights of 200 yards through the air.

These wonderful links help us to understand how land animals were evolved from fishes. So far, the vertebrates we have discussed are all water animals; we must now "land our fish" and watch his development into a dry-land creature. How many people would care to classify the objects in Fig. 102 at first sight? They look as if they represented only one group, but they belong to three distinct orders. The bottom one is a fish—the electric eel. The middle one is an amphibian (*Cæcilia lumbricoidea*), and belongs to the same order as frogs and toads. The top one is a reptile known as Amphisbæna, so called because it can crawl either end first. It is in reality a lizard that, by taking up a subterranean

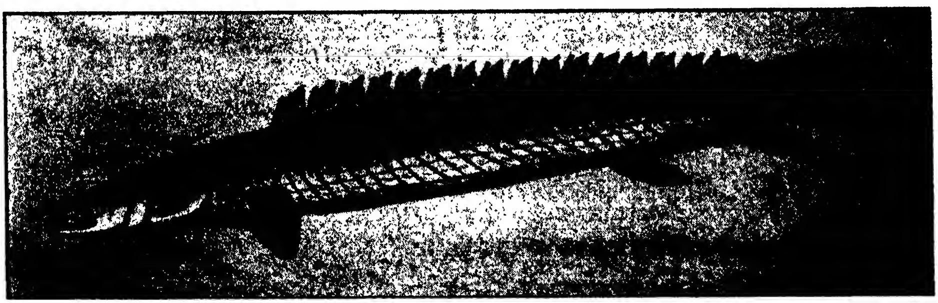
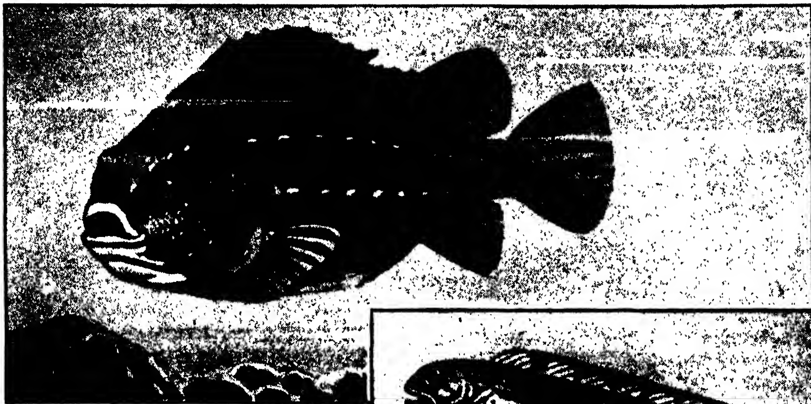


FIG. 96.—Polypterus bichir.

*Polypterus bichir* is a ganoid (bony) fish, a dweller of the Nile. It possesses a double air-bladder and external gills, but can live only four hours out of water. Nevertheless, it comes constantly to the surface to breathe, and drowns if kept forcibly under water. The back fin is not continuous, but serrated into a series of finlets. It is a very archaic type of fish, but no fossils are known. In diet it is carnivorous. The true lung-fish *Protopterus* and *Lepidosiren* also possess a double air-bladder.



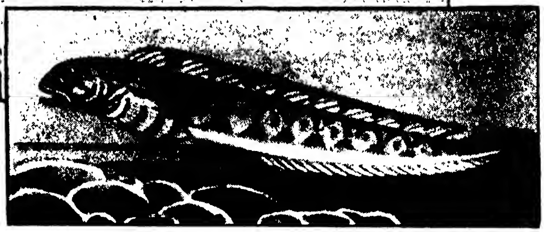


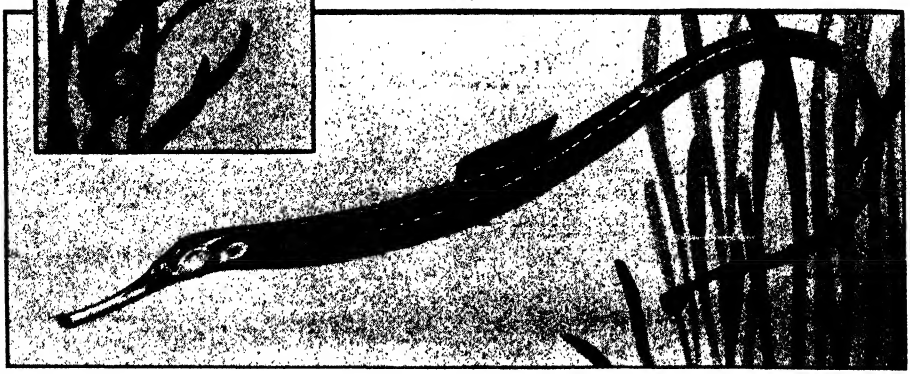
FIG. 97.—Lumpsucker and (below) Blenny.

The Lumpsucker (*Cyclopterus*) is about 1 inch in length, and frequents our coast. The male has a red-and-yellow colour, and will remain for several weeks on guard over the eggs.

The Blenny is viviparous, bringing forth as many as 300 live young at a sitting. There are sea and fresh-water kinds, and they include the Shanny, Gunnel, and Wolf-fish.

FIG. 98.—Sea-horse and Pipe-fish.

The Sea-horse (*Hippocampus*) and Pipe-fish (*Syngnathus*) both belong to the family *Syngnathidæ*. The ventral fins are modified into a brood-pouch in Hippocampus, reminding one of the marsupium of the kangaroo. In such brood-pouches, the males of both these fishes carry and hatch the eggs.



mode of life, has lost its limbs and most of its scales, and suffered a great diminution in the size of its eyes.

The extraordinary variety shown in the class of fishes is most striking, and, once we appreciate the fact of natural selection incessantly working on countless variations always present, we need not wonder that, of these, some were in the direction of life on land. But this mighty advance took a long time, for only by a series of multitudinous small structural changes

FIG. 99.—Climbing Perch.

The Climbing Perch (*Anabas Scandens*) is a teleostean fish of the rivers and estuaries of Africa. It can remain for a long time out of water, breathing by means of an accessory breathing apparatus at the side of the head, connected with the gills. It will sometimes climb a tree to a height of 5 or 6 feet.

FIG. 100.—Goggle-eyed Periophthalmus.

Periophthalmus, mud-skipper, or walking-fish, can live out of water for hours at a time. It lives in the rivers and estuaries of tropical Africa. The writer has spent hours trying (unsuccessfully) to catch one of these mud-skippers in the mangrove swamps of the Athi River, East Africa. Their rapid running along the surface of the mud, and their all-round vision, make their capture exceedingly difficult.

was it possible for a water-dwelling, water-breathing animal to turn into a land-dwelling and air-breathing one. The connecting links between the true fishes and purely terrestrial vertebrates are the *Dipnoi*, or "double-breathers," and the *Amphibia*, or "double-livers," both of which are capable of living in water and on land at some stage of their existence. The amphibians have had their day; they once reigned throughout the swampy lands, but are now represented by only about 1,000 species as compared with 250,000 species of insects, 3,000 species of fishes, and 10,000 species of birds. There is no doubt that amphibians have sprung from fish-like ancestors, and in turn have given rise to reptiles; they hold a position between the two, and are real connecting-links.

We have seen that some fishes possess a lung or lungs, or other accessory breathing organs that enable them to live out of water for a time, and it is among them, and especially among the Dipnoi and Crossopterygii, that we must seek the origin of amphibians. The Siren, or Mud-eel, possesses no hind limbs, and it retains its gills even after its larval or tadpole stage has been passed; it *seems* far nearer the fishes than is a toad, yet is a true amphibian.

The Newt, or Eft (Fig. 103), of our ponds and ditches, though a modern animal, resembles the Dipnoi in its arrangement for breathing. Such

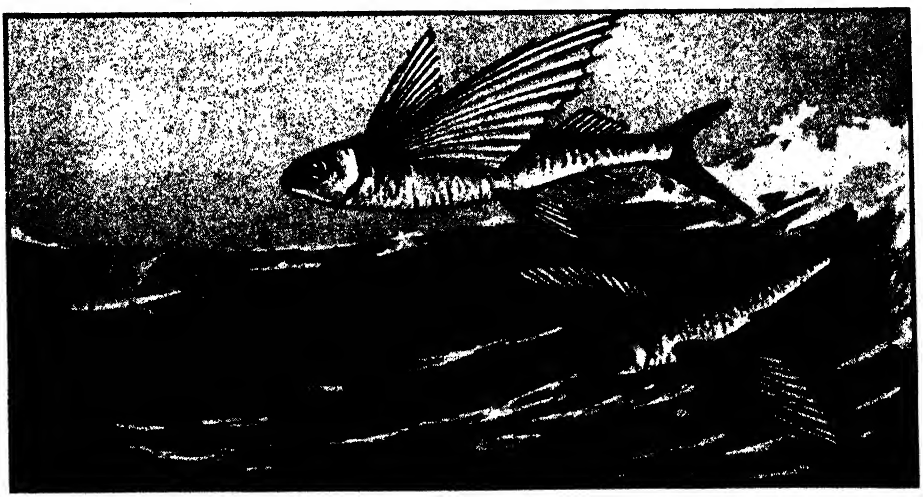


FIG. 101.—Flying-fish.

**The Flying fish, *Exocœlus spilopterus*, is as big as a mackerel. The African flying-fish, *Pantodon*, is only 4 inches long, is an inhabitant of the Kongo and Niger rivers, and can fly about 300 yards. The large pectoral fins and small pelvic fins play the part of wings. The tail fin gives the final impulse on leaving the water. The wings undoubtedly vibrate, but the flight is really that of a gliding plane. There are several extinct forms in Cretaceous.**



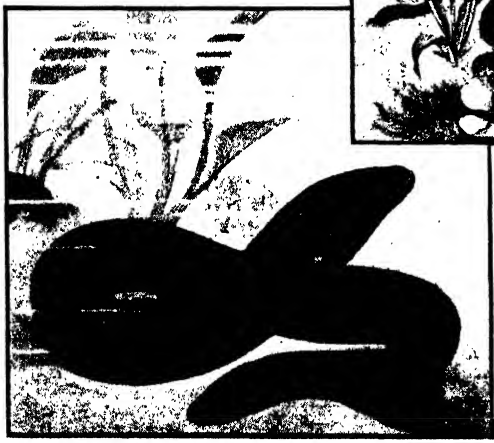


FIG. 102.—Reptile, Amphibian, and Fish.

creatures as the siren and eft help us to form a notion of the appearance of the earlier amphibians.

The Frog (Fig. 104) is a modern and specialized amphibian. From the "eggs" of the "frog-spawn" tiny free-swimming larvæ or tadpoles emerge. For a day or so they cling, by means of an adhesive disc, to the leaves and stalks of water-plants; then, using their tails, they begin to swim about, breathing in the oxygen dissolved in the water through their gills. Such is the fish-stage in this amphibian's ontogenetical evolution. After a time the tail becomes absorbed, hind-limbs appear, and, a little later, the fore-limbs. Gills now cease and lungs commence to function, and presently the young frog crawls out of the water, and, from being a fish, becomes an amphibian.

We come next to Reptiles, a word meaning "crawling things." They have scaly skins, and most of them very short legs; the class includes crocodiles, tortoises, lizards, and snakes. As can be judged from the numerous fossils found all over the world, the reptiles increased and multiplied to an amazing degree, until, finally, they had the land practically

FIG. 103.—Crested Newt or Eft, *Triturus cristatus*: male (below) and female.

The newts are familiar amphibians of our ponds. Unlike the frog, they cling to a life in the water. Amphibians are of great interest as being the class of animals that made the first successful experiment in exchanging an aquatic for a terrestrial life; prior to their taking this step the Dipnoi made a tentative trial. Amphibians breathe water by means of gills in the larval stage, and air by means of lungs in the adult stage. Amphibia also possess a three-chambered heart, as contrasted with the two-chambered heart of their predecessors, the fishes, and the four-chambered heart of their successors, the mammals. Significant, in the light of evolution, is the fact that the Dipnoi show the beginnings of a three-chambered heart.


FIG. 104.—The Eggs (frog spawn) and Larvæ (tadpoles) of the Common Frog, *Rana temporaria*.

The animal provides a story of evolution that can be seen in a glance.

The female frog lays her hundreds of unfertilized eggs which, as they pass to the exterior are fertilized by the sperm cells. The fertilized cells now lie in a connected group. Each cell

to themselves. We should always bear in mind that the vast majority of orders of reptiles are now extinct.

It is probable that, on the one hand, reptiles *evolved from* one or other of the "roof-headed" amphibians (*Stegocephala*) in the lower Carboniferous period, and that, on the other hand, some of them *evolved into* the Theromorphan, or breast-shaped, and bipedal (hind-leg) walking reptiles from which, respectively, sprang the primitive mammals and birds. Mammals sprang from these *Theromorpha* in early Permian days, while in the upper Permian, or possibly later in the Triassic, the birds branched off from a group of small lizard-like reptiles, which, like the Dinosaurs, had adopted a bipedal locomotion, especially when running, in which action they probably helped themselves along by a backward thrust of their upper limbs as does the ostrich to-day. Still later, possibly for purposes of safety, they took to climbing trees and so further developed the upper limbs in the direction of wings by practising "gliding leaps" from tree to tree, as do our present-day "flying squirrels" and "flying frogs." To us, reptiles are a very interesting class, for if mammals came through them, so also did man.

The Proreptilia class are, as their name "before-the-reptiles-proper" indicates, the lowest known forms. They link the Amphibia below with the higher Reptiles above; indeed, for a time they were mistaken for the roof-headed Amphibia with whose remains they lay amid the Permian rocks. The Prosaurians constituted a slightly higher stage, though they

surrounds itself with a tenacious, transparent jelly, the whole forming the familiar frog-spawn (1), fifth day. About the tenth day a tadpole appears inside what was an egg, but is now a spherical ball (2). About the twelfth day the minute tadpoles break away from the jelly of the spawn and swim about free, partly by means of cilia with which the whole of their bodies is covered. They shrink greatly in size, for they have, as yet, no mouths (3), and are feeding on the remains of the yolk that was in the egg-cell. At the same time they have developed a gland on the under-surface of the head, and this, secreting a sticky material, enables them to adhere to stones and water-weeds. This occurs about the fourteenth day (4). Their fish-like form is now (third week) very manifest. Three external gills have appeared on each side behind the head, and a relatively large fin passes completely around three-fourths of the body. About this stage the mouth appears, and communicates with the gut, so that the creature begins to feed voraciously on vegetable matter. About the seventeenth day they detach themselves from the solid objects and swim about free (5). When about five weeks old the external gills disappear (6) to give place to internal gills, which resemble those of Lepidosiren (7). When eight to twelve weeks old, horny jaws appear in the mouth, and limbs suitable for land locomotion begin to appear; first the hinder ones (8) and then the front ones. The lungs are also beginning to function, and the animal comes frequently to the surface of the water to gulp down air (9). At the twelfth week all four limbs are present (10). The circulation, hitherto aquatic and fish-like and controlled by a fish-like two-chambered heart, is becoming suited to a land-dwelling existence; blood is being diverted from the gills to the lungs, and the heart is becoming three-chambered. When about four months old the animal ceases to feed, being now nourished by its tail, which it is fast absorbing (11). A month or so later the tail has disappeared; it is feeding on flies and worms, for it has left the water: the vegetarian fish (11) has become a carnivorous amphibian (12).

FIG. 105.—*Sphenodon*, or *Hatteria Punctata*.

Belongs to an ancient Order, the *Rhyncocephalia* (Snout-Head). A living fossil closely allied to the Triassic *Hyperodapedon*. It is a nocturnal reptile known to the natives of New Zealand as the Tuatara, and is 1 to 2 feet in length. It has a parietal or pineal eye beneath the skin of the head, with lens, retina, and optic nerve. The retina, however, appears to be insensitive to light. There is a hole in the skull, beneath the eye, through which the optic nerve passes to the brain. There can be no doubt but that in ancestors it was functional. It also appears to have been functional in many extinct reptiles and amphibians, such as the Labyrinthodonts. Many living animals show traces of a pineal eye; for example, our common "blind-worm," really a limbless snake (*Anguis*), also in the lamprey, iguana, and even in the tadpole. The embryos of many mammals also show its remains (see Fig. 107). There are two kinds of unpaired (cyclopean) eyes that exist as relics in present-day animals: (1) the parietal eye and (2) the pineal eye; and as a rule, when both are present together, they are in close association. Cyclostome fishes possess both. Anurans (frogs, etc.) possess a well-marked pineal organ connected with the epiphysis and ending in a nerve-like tract terminating in the mid brain. In certain reptiles the parietal eye comes to the surface of the skull. In mammals the parietal eye has disappeared, while the pineal eye has evolved into a gland of probable endocrine function. In some of the ancient reptile-like creatures a single eye was probably functional.

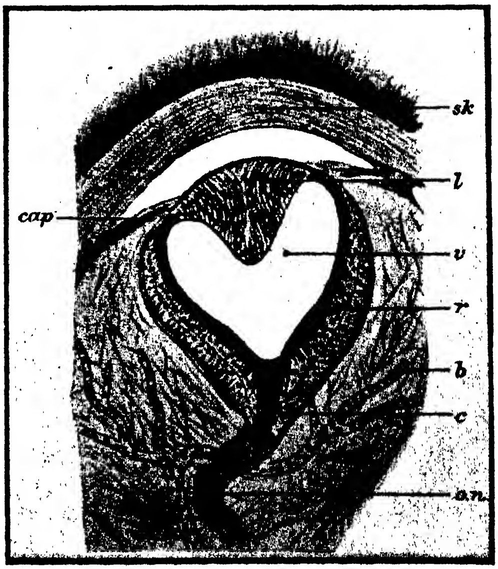



FIG. 106.—Section through Pineal Eye of the reptile *Hatteria*, or *Sphenodon*.

*Sk*, skin and tissue covering head; *cap*, capsule of eye; *l*, lens; *v*, vitreous chamber filled with clear fluid; *r*, retina; *b*, blood-vessels; *c*, cells linking up retina with optic nerve (*o.n.*).

*From Dr. R. Wiedersheim's "Structure of Man" (Macmillan).*

still retained many of the primitive features of their amphibian forebears. They were, for the most part, small newt-like animals—again of the Permian period—with five fingers and toes.

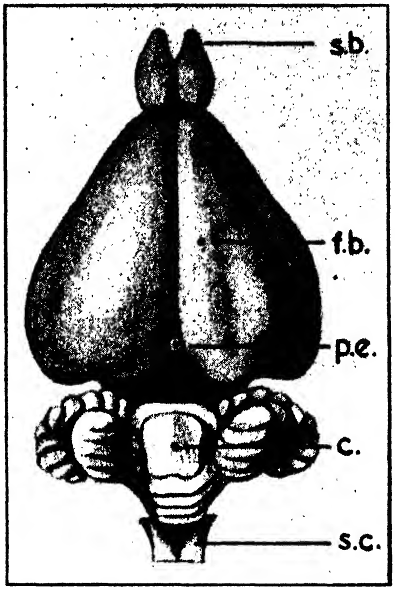



FIG. 107.—Upper surface of Rabbit's Brain, showing the remains of the Pineal Eye.

In front is the relatively large smell-brain (*s.b.*) behind which is the smooth fore-brain (*f.b.*). The remains of the pineal eye (*p.e.*) can be seen below and between the hinder borders of the fore-brain. The little brain, or cerebellum (*c.*), and spinal cord (*s.c.*) are also shown.

Only one species of these Prosaurians (*Sphenodon punctatus*) exists to-day, and that lives in New Zealand in the pride of antiquity. Think what the ancestors of this remarkably conservative creature must have seen; they witnessed the headlong downfall of the mighty reptile rulers which had conquered air, land, and water, the advent of egg-laying mammals, and the revolutionary advance of the warm-blooded, viviparous, milk-giving mammals. They saw the several stages through which certain of their cold-blooded, scale-covered, sluggish, toothed cousins developed into feverishly active, hot-blooded creatures with beaked jaws and feathered skins. They saw, too, the drab earth become covered with gay-coloured flowers; and, finally—geologically speaking, but a few years ago—they were witnesses of the transformation of that particularly insurgent mammal, ape-man, into man, and, in the latter, of the subordination of muscle to brain!

The *Sphenodon* (Fig. 105), also known as the *Hatteria* or *Tuatara*, the "Spiny one," as the Maoris call it, is not a lizard, but a very generalized type of primitive reptile, the last living witness of the long bygone Prosaurians. It is said to be incorrigibly lazy, sleeping most of the day in the water, below the surface of which it can remain for hours without breathing, coming out in the cooler hours to feed on worms and insects. Owing to its having been mercilessly hunted by the Maoris, this "living fossil" has become so rare that steps have had to be taken by the New Zealand Government to prevent its following the example of the Dodo of Mauritius, which was exterminated in 1681 by the Dutch immigrants and their pigs. The interesting evolutionary point about Hatteria is that it has

retained, in a probably slightly functional form, the pineal eye at the top of its head, with retina, lens, and optic nerve all present (see Fig. 106). Remains of this "third eye" (as it is wrongly called) are present in lampreys, frogs, and lizards, and can sometimes be seen in the frog on the top of the head, between the normal lateral eyes, as the so-called Stieda's organ. In the extinct Amphibia and reptiles of the Palæo- and Meso-zoic periods, this median eye, or rather pair of eyes, was much better developed. Recent embryological research has demonstrated that the remaining pineal eye in *Sphenodon* is the *left* eye of the ancestral pair, while that in the lamprey is the right one. Birds and mammals also possess vestiges of this extra median pair of eyes. In man this vestige, the pineal organ, was thought by Descartes to be the seat of the soul, owing to its lofty and symmetrical position. In ourselves and mammals generally the *present-day function* of the organ is to manufacture and pour out into the

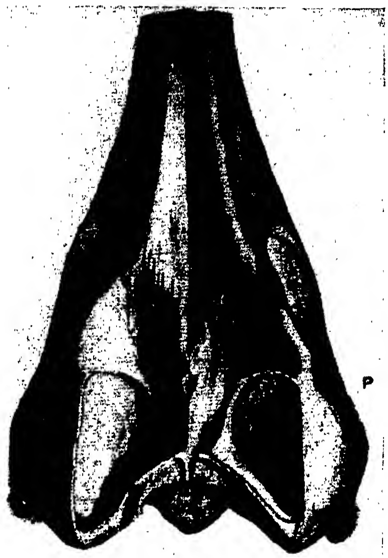
FIG. 108.—Drawing to show the probable appearance of an Ichthyosaurus swimming beneath the surface of the water. (See Fig. 109.)

This extinct reptile flourished in the Trias–Cretaceous period. It was so highly specialized to aquatic life that it was very fish-like in appearance. It was a carnivorous animal, and both jaws were lined with formidable teeth. Some forms attained a length of over 40 feet. There is a parietal foramen in the top of the skull, so it is more than probable that a pineal or paired pineal eye functioned in addition to the two huge lateral eyes. The backbone was made up of biconcave vertebræ, like that of a fish. The nostrils were not at the end of the snout, but, as in the whale, on the top of the head, this being the part of the body to break surface first—obviously a device to facilitate air-breathing. Locomotion was effected by paddles—modified legs—and the powerful caudal "fin"; this last was vertical, as in the shark and other fish, and not horizontal, as in the whale.

blood-stream certain chemical compounds which exert a powerful influence on the development and growth of the primary and secondary sexual organs.[1]

The Theromorphan reptiles include, among others, the Pariasaurs (Fig. 63, p. 67) and Theriodonts, or reptiles with mammal-like teeth (Figs. 64 and 65). As already stated, it was probably through the Theromorphs that the genealogical line of the mammals passed.

All the reptiles of this sub-class are now extinct; the earliest known occur in the lower red sandstone of Thuringia and Bohemia, and in the middle Permian of Russia.[2]




*From Sir Ray Lankester's "Extinct Animals" (Constable).*

FIG. 109.—Photograph of the upper surface of the Skull of an Ichthyosaurus.

On a level with the letter P, in the middle of the skull, is seen an oval pit, the "parietal foramen," in which was lodged a "third" eye.

The Plesiosaurs (near-reptiles), Dolichosaurs (long-reptiles), Ichthyosaurs (fish-shaped reptiles) (Figs. 108, 109), Pterosaurs (winged reptiles) (Figs. 68 (p. 70), 110, 111), and Mosasaurs (Meuse reptiles), all flourished in the Jurassic-Cretaceous ages and then died out. Ichthyosaurus (fish-lizard) provides a good instance of zigzag evolution; originally a fish, it took to dry land as an amphibian, became a land reptile, returned to the sea and became a water reptile. Finally, it so adapted itself to aquatic life that it assumed a fish-like form. But Evolution never forces back a type it has brought forth into the type from which it has come; a "lung," for example, once evolved never reverts to a "swim-bladder," nor a "hand" to a "fin." The Ichthyosaurus had to keep up lung-breathing, and under the skin of its fore-paddles, despite their fin-like look, the old terrestrial hand still persisted, though the fingers in certain types showed an increase from the generalized pentadactyle pattern to six or even seven

[1] The main function of the pineal organ of present-day man is to retard the action of the *hormones* or *endocrines* of other organs—e.g., *pituitrin, thyroxin, insulin, oestrin*—and the *testicular hormone* of the pituitary, thyroid, pancreas, ovary, and testis respectively. The pineal organ is thus a super-endocrine organ that checks over-activity on the part of any member of the endocrine system.

[2] As this book goes to press comes an announcement of the discovery, in a back-water of the Middle Volga, of a 12 ft.-long reptile-mammal, a deinocephalian that has been named *Titanophoneus potens.* It is a true link between the reptiles and mammals.

digits. Some Ichthyosaurs were but a few inches long; in others the *skull alone* measured 6 feet. Some few may have laid eggs, coming ashore to the sand for that purpose, but others became so specialized to aquatic life that they brought forth their young in mid-ocean, as do whales and dolphins. This has been proved by the finding of certain fossil skeletons inside which were the more or less perfect fossil bones (thus showing they had not been swallowed) of unborn young. Finally, some of these sea reptiles possessed a median pair of eyes at the top of the head in addition to the pair of lateral eyes (Fig. 109). Few people would see any connection at first sight between a snake and a bird. But if we compare certain of the bird-like reptiles with a modern bird stripped of its feathers, we see very distinct resemblances. Reptiles are scaly animals, while birds are feathered ones. Phylogenetically—that is, in the history of the race—feathers are really scales that have become elongated, softened, and frayed out; ontogenetically—that is, in individual development—both feathers and scales are specialized developments of the outer horny layer of the skin.

Ramphorhyncus (Fig. 110) was a reptile that had membranous wings and flew like a bird. This Pterosaur, or Pterodactyl, flourished in the Jurassic-Cretaceous times and its remains have been found in Bavaria. The Pterodactyls varied in size from a sparrow to creatures with a wing-span of 26 feet. The Pterosaurs (wing reptile, to use the more comprehensive term) had well-developed brains, and eyes not unlike those of birds. The large eyes were probably capable of rapid focussing. Pteranodon was a fish-eating Pterosaur which had a bony projection at the back

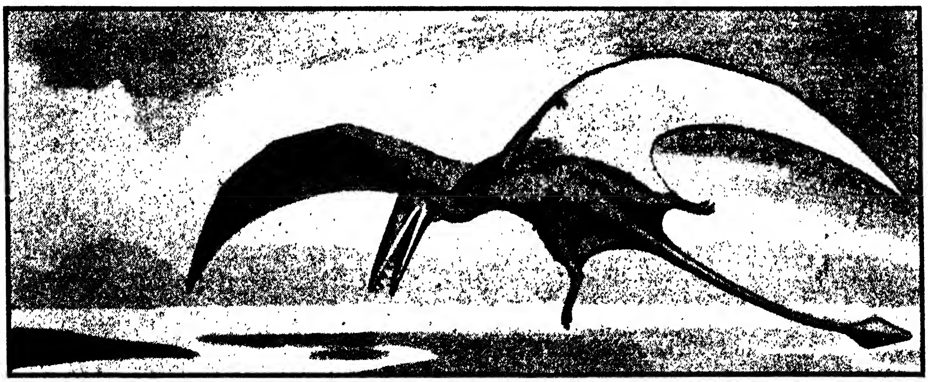


FIG. 110.—Ramphorhyncus Phyllurus.

A flying reptile with a very long tail. It was large-eyed; the patagium, or wing-membrane, extended from the enormously long fourth finger to the tail, thus leaving the claws on the hind feet free. Note, too, the three fingers at the extremity of the forearm.

of its head to balance its long jaws. The humerus of Pterosaurs had a foramen connecting the central hollow of the bone with the respiratory organs and the bird-like feature. They flourished in Jurassic - Cretaceous periods. Possibly the common ancestor of birds and pterosaurs was in the Permian. In Fig. 111 the one at the top is a *reptile*, a wing-fingered Pterodactyl. Observe that it is the finger that corresponds to our fifth that is greatly prolonged to support the wing. The bones, like those of a bird, are hollow and filled with air. In size these creatures varied from a robin to an eagle. The central animal of the figure is a *mammal*, a bat, while the lowest is a *bird*. The picture exemplifies in three totally different classes of animals (reptiles, mammals, birds) organs (arms) that possess both an *analogous*—that is, an adaptive—and a *homologous*—that is, an anatomical—resemblance. Such resemblances form what is known as *convergence* in evolution in conformity with some common habit—in this case flying.

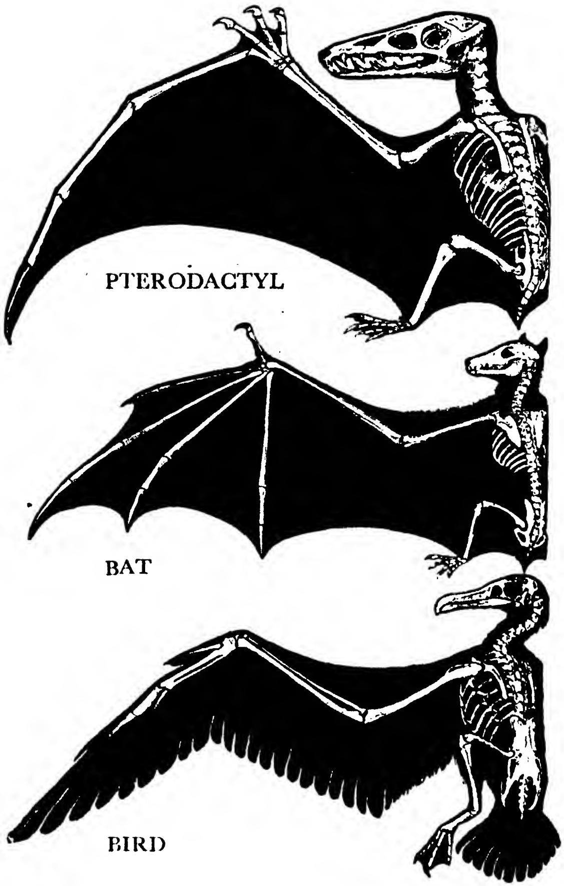



FIG. 111.—Wings of Reptile, Mammal, and Bird.

The wings of these three different classes of animals are *homologous* organs, for they are alike in structure; but they are also *analogous* organs, for they possess the common function of *flight*. In the history of vertebrates, true flight—that is, flight by wing movements as opposed to gliding flight—has arisen four times: in fishes (flying-fish), reptiles (pterosaurs), birds, and mammals. True, the chief mode of flight in the flying-fish, as it is in certain pterodactyls, is that of vol-planing, or gliding, but flying-fish undoubtedly lengthen their range of flight by wing-flapping.

Fig. 112 shows the Archæopteryx ("the old bird")—well named, for

FIG. 112.—Archæopteryx Macrura. A Reptilian Bird of the upper Jurassic (Solenhofen Limestone, Bavaria). It was as large as a crow and is a connecting link between reptiles and birds. There is a claw on each of the three free fingers. The patagium of ancestral flying reptiles is vestigial. The primary feathers, or remiges, are borne on the hand, the secondaries on the arm. The jaws are toothed; and, like reptiles, it bears abdominal ribs, and supports a long tail, on either side of which steering feathers, or rectrices, are arranged. On the right (below) is a part of the tail, showing the arrangement of the feathers. INSETS: (*Top*) Skull, showing teeth; (*Bottom*) The fossil Archæopteryx, from the Solenhofen limestone of the upper Jurassic.

There are two specimens of this reptile-bird extant: one in the British Museum is headless; the other, in Berlin, is more perfect.

it is indeed the oldest known member of the feathered tribe, its remains being found in the same rocks as the flying reptiles. It was rather smaller than a crow, and united some of the characters of reptiles with those of a true bird; for instance, it had four well-developed toes, three of its fingers ended in claws and were free, and it had teeth, and a reptilian tail in which each vertebra carried a pair of quill feathers. It was, in fact, a link in the evolutionary chain, a creature that had been reptile but was not yet bird—a true reptile-bird. Despite their many extraordinary resemblances (for instance, the nostrils, the neck vertebræ, shoulder-blades, fibulæ, the pre-orbital foramina, the brain, hollow bones, warm blood, etc.) to the birds, the Pterosaurs were true reptiles: they were not even reptile-birds. They, the mammals, the reptile-birds, and birds, had been shunted off the main reptile line along three distinct and separate branch lines.

There is a weird bird of New Zealand, known as the Apteryx or Kiwi (Fig. 113), which has entirely lost the power of flight. So rudimentary have its wings become in consequence of disuse that they must be searched for amid the long hair-like feathers. It passes the day in a burrow, coming out at night to probe the ground with its long sensitive beak and "smell out" earth-worms by means of its nostrils, which, unlike those of other birds, are situated at the very tip of the upper beak.

Kiwis are the smallest members of a widespread and big-bodied family, to which the ostrich and emu belong; in historical times New Zealand had the largest specimen of this family, the Moa (Dinornis), which had thigh-bones longer and thicker than those of a horse.

As we are naturally more interested in mammals, these few examples of birds must suffice to show that the most unlike animals have come, by different lines, from the same ancestors. So, when you see a cat stalking a sparrow, remember that both animals, despite their very different habits and appearances, have come through reptiles from the same group of roof-headed amphibians. You cannot cross laterally from one side line or branch of a genealogical tree to another, but if you trace all the side lines or branches far enough back you will find they converge to meet in great centres, which represent the common ancestors.

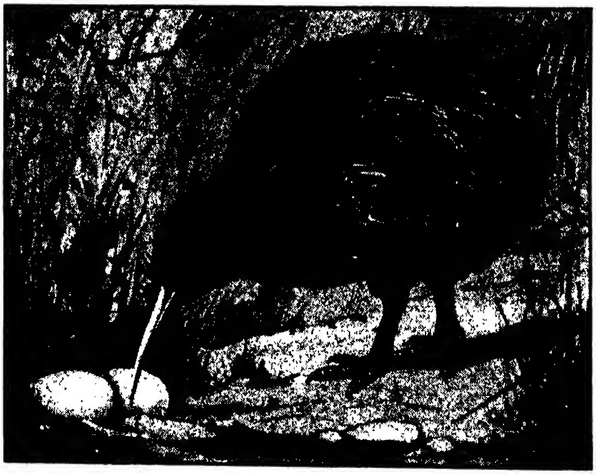


FIG. 113.—Kiwi, or Apteryx.

Like the Cassowary, Rhea, and Ostrich, the Kiwi, or Apteryx, is a running, flightless bird found in New Zealand. It is allied to the recently extinct large Moa of New Zealand. It belongs to the Division Palæognathæ. It lays two eggs, relatively very large; for each egg measures 3 inches × 5 inches and weighs one-third of its own body weight, which is about equal to that of a small hen. Significantly, another extinct bird allied to the Kiwi is the Æpyornis of Madagascar, which also laid relatively huge eggs, each holding six ostrich eggs (contents). The nostrils of Kiwi are at the *end* of the long beak instead of being, as in most birds, at the base. The feathers at the base are bristle-like, and no tail feathers are perceptible. The wings are rudimentary, and for this reason the clavicles, or collar bones, have vanished. The bird is nocturnal, and feeds on earth-worms.

# CHAPTER FIVE: ZOOLOGY (MAMMAL, MONKEY, APE, MAN)

IN this chapter we trace the evolution of mammals; for us the most important group of all, since it is the one to which we belong.

The better to understand the method of Evolution it will be well to bear in mind three general principles:—

(1) Animals that have developed along side lines have no participation in the evolution of man. Birds, for example, in no way figure in man's ancestral pedigree, for they are in a side-branch that left the main reptilian stem at one point, while mammals and man are in another side-branch that left the same stem at a different point. Modern birds, modern reptiles, modern mammals and man are the terminal leaves, so to speak, of twigs and branches that have diverged from a common pro-reptilian stem or stock.

(2) Over-specialization and over-growth are potent causes of extinction.

(3) The larger and more highly specialized animals have evolved from smaller, simpler, and more generalized types.

Many of these earlier and simpler forms have become extinct, because in the struggle for life they were destroyed by the later, more specialized, animals. Yet here and there, in out-of-the-way corners of the earth, a few have survived; and by means of these and the fossil ancestors found in the rocks we are able to trace the evolution of many families of animals with remarkable clearness.

Fig. 114 shows a familiar mammal. Without exception all animals the females of which suckle their young are called "mammals" (*mammæ*, breasts). There are many other distinguishing marks, but this one is sufficient.

Viewed externally, Fish are distinguished by their fins, Reptiles by their dry, horny scales, Birds by their feathers, and Mammals by their hair. We must remember, however, that such very unlike structures as scales, feathers, hair, wool, nails, hoofs, and claws are in origin identical, being but modifications of skin-cells. Scales are still found on armadillos, as well as on the legs of birds; and practically all the fingers and toes of mammals have either nails or claws, which are modifications of the scales of reptiles. The dappled markings on some horses are probably aftermaths of the scales of far-back ancestors. The present writer has fre-

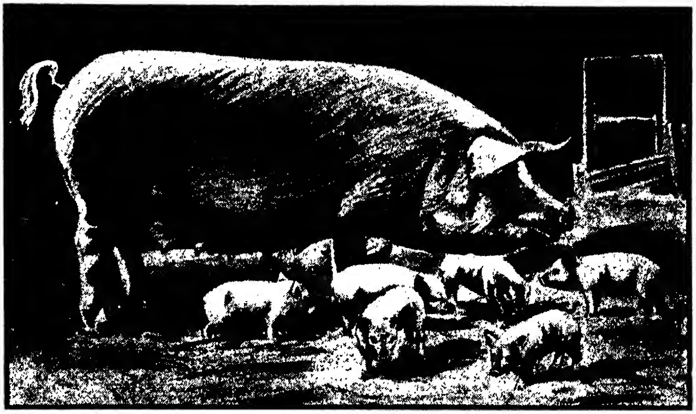


FIG. 114.—A Domestic Sow and her Young.

Such, and most other, domestic animals are "artificially" protected by man. If returned to the wild they would quickly die through inability to fend for themselves.

quently observed polygonal-shaped patterns on the human skin (especially in cold weather) that are probably explainable in similar terms.

Mammals are divided into three classes: (1) The primitive mammals, or Prototheria; (2) the modified mammals, or Metatheria; and (3) the perfect mammals, or Eutheria. Fig. 115 shows a mammal and a reptile. It would puzzle anyone not conversant with biology to imagine how the cow could be related to the lizard. Note that Evolution does not teach that the cow *came from* the lizard, but that all existing mammals, including of course the cow, and all existing reptiles, including the lizard, have come

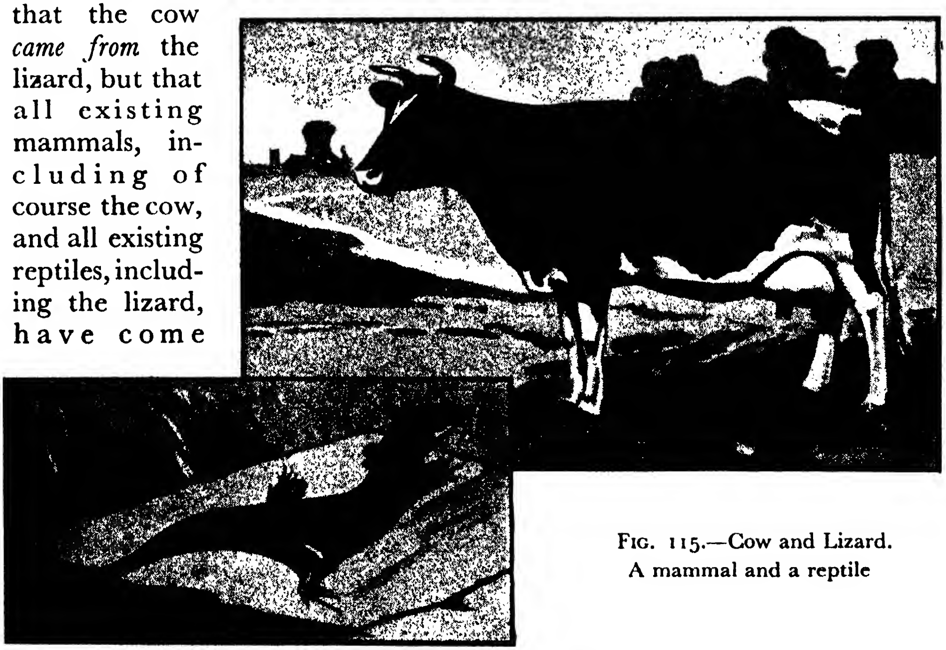


FIG. 115.—Cow and Lizard. A mammal and a reptile

FIG. 116.—Duck-billed Platypus, Duck-mole, or Duck-bill, *Ornithorhynchus anatinus*.

A real living fossil with affinities to mammals, birds, and reptiles. It inhabits the stagnant pools and sluggish rivers of Australia and Tasmania in company with another living fossil, *Neoceratodus*. It is oviparous, laying two eggs, each ¾ inch long. The brain is smooth and poorly developed. The skeleton presents many reptilian features. The males carry a spur on the heel for fighting other males. The body is covered with a soft fur. Its temperature is midway between that of "warm-blooded" mammals and "cold-blooded" reptiles, about 26° C.

*through* a particular *group* of ancient reptiles, the several members of which were descendants of a common proreptilian ancestor. We should commence our study of the mammals, not with a highly specialized type like the cow, but with a primitive one such as the duck-billed platypus (Ornithorhynchus) (Fig. 116). This is, without doubt, one of the most curious animals in the world; indeed, when first brought to this country it was believed to be a deliberate fraud, like the mermaids which used to be made by neatly stitching together the forepart of a monkey and the tail of a salmon! The Platypus, or duck-mole, whose home is in Australia and Tasmania, is a representative of one of the two families of primitive mammals, the other family containing the Spiny Ant-eaters of Australia, Tasmania, and New Guinea; both families, the *Echidnidæ* and *Ornithorhynchidæ*, forming the Order *Monotremata* of the sub-class Prototheria or First Beasts. The Platypus is a little larger than our mole, 18–20 inches long, and is covered with a dense dark brown fur; the limbs are short and five-digited, all the fingers and toes being webbed, but, as you can see in the picture, the webbing on the fingers extends

FIG. 117.—Great Kangaroo (*Macropus giganteus*) and the Rock Wallaby.

The Rock Wallaby is a small kind of Kangaroo, a terrestrial marsupial of Australia. The marsupials belong to the sub-class metatheria, of the class mammals; below them are the monotremes, of the sub-class prototheria; above them are the placental mammals of the sub-class eutheria.

INSET: Immature Kangaroo removed from a teat in the mother's pouch.

considerably beyond the tips of the claws, as in seals, but leaves the claw-tips free in the case of the feet. The swimming membrane is in the hand, but, when this is used for digging, the membrane is folded back on the palm, leaving the claws free. The beak is broad and flat, and suggests that of a duck; it is not, however, covered with horn, but with a soft, sensitive, naked skin. The brain is smooth, and there is no *corpus callosum*, or band of nervous matter uniting the two hemispheres of the cerebrum, as in the higher mammals. It has three real mammalian teeth in each jaw in the earlier part of its life, but as these get worn down they are shed just as are milk teeth, to be replaced by horny plates. As might be expected, these teeth show a general resemblance to those of certain fossil mammal-like reptiles. The duck-mole is aquatic, making a burrow in the bank of a stream; it lives on grubs, worms, snails, but with a special *penchant* for fresh-water mussels. In common with reptiles and birds, it lays two large-yolked eggs at the end of the burrow, which, however, are soft-shelled, being covered with a tough membrane, and are incubated by the mother in a nest within the burrow. She has a small pouch for the protection of the new-born young; but there are no teats for the young to suck, the milk simply soaking the hair around her milk-glands, whence it is licked off by the little ones. Instead of two vents, sexual and anal, there is only one, the cloaca, as in reptiles and birds. The testes are abdominal.

Of the many other points which indicate the intermediate position of the Monotremata between the reptiles and mammals, space will only permit of allusion to one. The blood of a higher mammal is relatively "hot," and its temperature is more or less constant—that is, it is not unduly influenced by the surrounding temperature. The blood of a reptile is relatively "cold," with, however, a wide range of temperature-variation that is directly related to changing temperature of the environment. If the monotrematous mammals, Echidna and Platypus, are really connecting links between the lower reptiles and the higher mammals we should expect their blood to be "neither hot nor cold," but lukewarm, and we should further expect it to have a fairly wide range of temperature-variation. Now, the temperature of these animals is actually intermediate between that of reptiles and the higher mammals, while the range of temperature-variation is very liberal, as much as 13° C., or 23° F., in the case of Echidna. Thus the very blood heat of these "Monotremes absurd, that lay eggs like a bird," reveals secrets of Evolution, for it informs us, *inter alia*, that the weird families comprised by the *Echidnidæ* and *Ornithorhynchidæ* are feeling their way, so to speak, from the *poikilothermal* reptiles to the *homœothermal* mammals.[1]

Let us proceed to the next group of mammals, the Marsupials (*marsupium*, a pouch). Fig. 117 shows the Rock Wallaby, which is of the same sub-family as the kangaroos. For the most part these pouched animals are found in Australia, though some kinds exist in the islands to the north of it. Many true mammals show the vestiges of a marsupium, an indication of the possession of this organ in far-back ancestors. Millions of years ago, in the Mesozoic epoch, they occurred in Europe and N. America in great numbers—a fact that explains the existence of a subdivision in S. America. The marsupial presents us with another "link-animal"; for, especially as regards gestation, its position is the mean of that of the Monotremata, or Prototheria (first beasts), which bring forth their "young" in the utterly undeveloped state represented by an egg, and the higher mammals, or Eutheria (perfect beasts, such as man!), inside the females of which the young complete practically the whole of their development. The gestation period is only five weeks, as compared with two weeks for the marsupial Opossum on the one hand, and 44 weeks for the placental mammal the horse. In the kangaroo the young one is born as a tiny, naked embryo about the size of the little finger, and in so helpless and imperfect a condition that the mother has to pick it up with her lips and place it to a teat inside her pouch. The little one

[1] *Poikilos*, various; *homoios*, like; *therme*, heat.

is provided with a special " larval organ " in the shape of a clasping mouth, and by this it clings pertinaciously to the teat though quite unable even to feed itself, its nourishment being effected by the mother squeezing her milk glands by special muscles and so forcing the fluid down its throat—in very much the same way that the mother whale feeds her young. The immature kangaroo can breathe and feed at the same time without choking; this it is enabled to do by means of a special prolongation from the larynx to the back of the nose. The " egg " of the kangaroo, which, as we have seen, is not extruded as in the Monotremata, but is retained within the female, is very small—a point in keeping with the type of ova in the typically higher Eutherian mammals. But at its first division the kangaroo egg divides incompletely, a feature reminiscent of the large-yolked eggs of reptiles.

Marsupials include kangaroos, wallabies, opossums, and phalangers, the last-named small, nocturnal, woolly, arboreal marsupials. In size they vary from that of a large dog to a rabbit, though the extinct kangaroo *Diprotodon Australis* was as

FIG. 118—Whale and Herring.

The *Orca*, or Killer-Whale, one of the most ferocious creatures of the seas. It has been known to attack man viciously. Its favourite meal is the tongue of the large whales, which it tears out of the mouth, leaving the mutilated victim to die on the top of the water. While the whale is a hot-blooded mammal that brings forth its young alive, the fish, shown in the upper figure, is cold-blooded and lays eggs.

large as a buffalo. Ancestral marsupials, to judge by certain anatomical evidence, were probably all arboreal. The hind legs were much larger than the forelegs, enabling the animal to indulge in bipedal locomotion. This it carries out by a series of leaps. A bipedal mode of progress has been evolved independently by certain lizards, dinosaurs, birds, rodents, marsupials, and man. In kangaroos the uterus and vagina are double. The vermiform appendix is long and not unlike that of the embryo of man.

In many points the Metatheria are an advance upon the more primitive monotremes: they have developed a clavicle, possess teats, and their cerebral hemispheres are furrowed and connected up by a rudimentary *corpus callosum*. Though in their general structure they hold a position midway between the primitive mammals and the mammals proper, yet it is not considered that any marsupials of a type such as those existent to-day are in the direct line of evolution of the higher mammals. Marsupials are a distinct side line, but with numerous and widespread ancestors, and as regards the present families we cannot say more than that they help us to understand some of the gradual stages through which the higher and more perfect mammals probably passed. All that is known with any degree of certainty concerning the origin of mammals as a whole is that somewhere about the time of the Permian-Triassic age a group of mammal-like reptiles branched off from the main reptilian stem and then broke up into further branches representing animals with quasi-mammal characteristics. These branches were—(1) Cynodonts, (2) Protodonts, (3) Triconodonts, (4) Multituberculata, (5) Trituberculata, (6) Archaic Monotremata, (7) Archaic Marsupialia, and (8) Archaic Placentalia or true Mammalia, the females of which nourish their unborn young through the mediation of a placenta.

It is in the Triassic rocks we first meet with the remains of undoubted mammals. When they did appear on the earth it was in a "tentative and hesitating way," for they were small and surrounded by huge, fierce carnivorous reptiles. These early and primitive mammals lingered to the Eocene period. In the bed of rocks next above the Trias—that is, the Jurassic—three groups of small animals have been found. One of these groups contains the *Primitive Insect Feeders*, among which *Amphitherium prevostii*, found in Stonesfield slate, near Oxford, was a creature about the size of a rat. Our modern Insectivora can be traced back to shrew-like creatures, our Carnivora to the Creodonta (flesh-toothed), and our Ungulata to a group represented by Phenacodus—all three types belonging to the Eocene. The earlier members of the higher mammal stock, to which we shall return in due course, were small creatures with long

slender tails, five-toed hands and feet, forty-four teeth, and a small head and brain.

Before we deal with our proximate ancestors we may as well dispose of two remarkable groups of mammals. In Fig. 118 the two animals look much alike; but the top one is a fish, the herring, while the bottom one is a mammal, a killer whale. There are many families in the class of whales. Perhaps the best known is the rorqual (Fig. 119). You can see what a gigantic beast this is. It has been known to measure over 100 feet in length, and to weigh several tons.

Whales preach so eloquent a sermon on Evolution that they call for somewhat detailed attention. They are warm-blooded, hairless, marine animals that bring forth their young alive and suckle them on milk. Their position in the Class Mammals is a moot point, but biochemical examination of their blood indicates a close relationship to the pig family (*suina*) of the even-toed hoofed animals (*Artiodactyla*). Whales breathe air by means of lungs, possess non-nucleated red blood-corpuscles which are pumped through the system by a four-chambered heart; they also have a well-developed brain, paddle-like arms, but have lost their legs. Although their superficial appearance is that of a well-streamlined fish, they belong to the Class Mammals and to the Sub-Class Cetaceans. They are divided into two Sub-Orders: the *Odontoceti*, or Toothed Whales, and the *Mystacoceti*, or Whalebone Whales. The former include *Physeter*, the Sperm Whale; *Globicephalus*, the Ca'ing Whale; *Orca*, the Killer; *Monodon*, the Narwhal; *Phocaena*, the Porpoise; and *Delphinus*, the Dolphin. Among the *Mystacoceti* are *Balaenoptera*, the Rorqual; *Megaptera*, the Humpback; and *Balaena*, the Greenland or Right Whale. Whales are chiefly salt-water inhabitants; but a few frequent the brackish waters of estuaries, and one or two have taken up their abode in fresh water. There is, for instance, an almost blind Dolphin that lives in the Ganges; the Guina River Dolphin is equally at home in fresh or salt water; the White Flag Dolphin is perhaps the whale that has most perfectly adapted itself to a fresh-water existence, for it inhabits the Tung Tin Lakes, 600 miles up the Yangste Kiang River.

Ancestrally, whales have led an erratic career, following a course that has been anything but straightforward. The far-back fish-progenitors of all the mammals left the ocean as lung-fishes some 350 million years ago, in the Silurian-Devonian period. Passing through amphibian and proto-mammal stages, first amid swamps and then on the dry land, they developed into true, or placental, mammals and as such once again entered the ocean, in all likelihood using rivers and marshes as a stepping-

FIG. 119.—Rorqual (*Balænoptera*).

One of the largest of the Whalebone Whales. Note the horizontal tail-fin. The pectoral fin is a modified front leg. Beneath the skin it still shows the bones of the old terrestrial fore-leg, four finger-bones, as many of the hand, carpal, or wrist-bones, the ulna and radius of the forearm, the humerus of the arm, and the scapula of the shoulder.

stone thereto. This momentous event probably occurred 60 million years ago, in early Eocene days. They attained their zenith in this new habitat, both as regards numbers and world distribution, about 12 million years back, in Miocene–Pliocene times (Fig. 53).

The largest whales are the Sulphur Bottom, the Greenland, and the Sperm (Fig. 120), the last so-called because it yields the valuable spermaceti. The Sulphur Bottom, *Sibbaldus Sulfureus*, may be 100 feet long, and could easily accommodate inside its skeleton a standing full-grown African Elephant. At the other end of the dimensional scale are certain Dolphins which, when full-grown, are only about 18 inches in length.

All whales are carnivorous; the Toothed Whales feed on fish, squid and octopuses, and one of them, the killer, has actually, as we shall see later, taken to a vile form of cannibalism. Whalebone Whales, feeding on pelagic fauna, are to that extent carnivorous, but since they cannot well avoid swallowing pelagic flora as well, they must be included in the category "omnivorous." The depth to which a whale will "sound"—as a deep dive is termed—in its search for an octopus is almost incredible. In 1932 a Sperm Whale became entangled in a submarine cable off Columbia at a depth of 3,240 feet. Sea-water, volume for volume, is heavier than fresh water, and consequently at any given depth exerts a

greater pressure. Thus, at a depth of a mile, sea-water pressure is 2359 lb., or 1·053 ton per sq. in., while fresh-water pressure is 2,289 lb., or 1·016 ton per sq. in. One of the deepest parts of the ocean is the Swire Abyss, in the Pacific, where the depth is 35,433 ft., or 6·71 miles; and here the pressure is 15,847 lb., or 7·042 ton per sq. in. It is highly probable that water-breathing organisms, such as the deep-sea luminous fishes, exist at this depth insensitive to the terrific pressure their bodies sustain; but air-breathing animals, such as the whale, could not possibly do so, for their chest-walls and lungs, or other air-breathing apparatus, would be instantly crushed and rendered immobile. A whale stranded on the sea-shore, under the comparatively paltry pressure of 14·7 lb. per sq. in., dies of suffocation through sheer inability to raise its chest-walls and suck the air down into its lungs; immersed in the sea, it breathes with ease because of the buoyancy the salt water gives to its body. The Sperm Whale, alluded to above, that was made a prisoner by the cable at a depth of 3,240 feet, was under a pressure of 1,441 lb. of water and 14·7 lb. of air; that is, under a total pressure of 1,455·8 lb., or 0·65 ton per sq. in. of its body-surface.

If a whale rises too quickly from the depths to the top of the sea, bubbles of nitrogen gas escape from solution in the blood and other fluids and block the vessels supplying important organs, especially the brain and spinal cord, resulting in a paralytic condition known to divers as "caisson disease" or "diver's paralysis." How whales tolerate the great pressures they do while making a deep sounding is a mystery to zoologists. There are in their tissues certain little-understood structures which are thought to be concerned with sensitivity to, and adjustment to, changes of pressure. Toothed Whales possess, for instance, thick networks of arteries and veins called "vascular pads" around the spinal cord in the neck region. Porpoises possess a specialized collection of fatty tissue, known as the "melon," in front of the blow-hole. Whalebone Whales possess no "melon," but bear on the snout some 130 highly specialized bristle-hairs, richly supplied with nerves, which would seem to play a similar role to the "melon."

The lung capacity of a 100 ft. whale is of the order of 600 cubic feet; its normal time of submergence is 20 minutes, though, when terrified by the whaler's harpoon-guns, it has been known to stay under water for two hours. When approaching the surface for the purpose of taking a deep breath to replenish its used-up oxygen, the effete air is forced out of the blow-hole while the creature is still a foot or so below the surface. This air, heated to the whale's blood temperature—which is 99° F., like

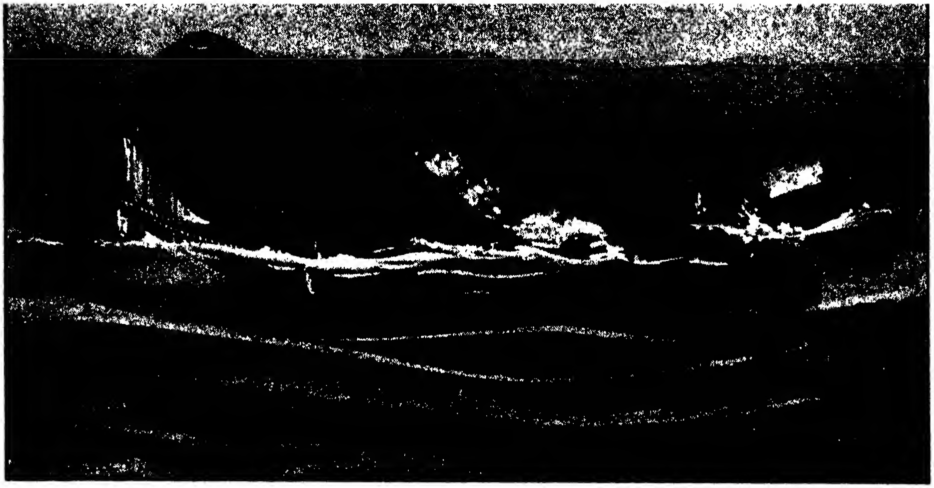


FIG. 120.—Sperm Whale.

The Sperm Whale is, alas, owing to the onslaughts of man, rapidly nearing extinction. So, for that matter, are the other giant whales, the Rorqual, etc. Teeth are sometimes absent in the upper jaw of the Sperm Whale, and in the Whalebone Whales their place is taken by the baleen, or whalebone.

our own—escapes under pressure and carries with it a spray of water and condensed breath which, together, form the well-known " spout," visible, in clear weather, for 2 or 3 miles.

Whales, especially the Dolphins, are beautifully streamlined; their average speed is 11 knots or 12½ m.p.h., but when at play and " showing off " they have been known to draw circles around a destroyer doing 40 m.p.h. The Finback Whale is one of the fastest denizens of the seas.

Among important adaptations of the whale to its comparatively recently adopted life in the ocean is an extension of the larynx to meet the hinder portion of the nasal cavity, a device which enables the young to feed and breathe at the same time, reminding one of an analogous contrivance in the suckling kangaroo. The blow-hole of the whale is another respiratory adaptation. In the whalebone kinds the external nostrils remain separate to terminate in two blow-holes, and these are shifted backwards to open on the top of the head, the first part of the body to gain the open air after submergence. In Toothed Whales the nostrils are united into a single blow-hole. In ourselves, and most mammals, the nose opens into the throat, but in Whales it connects directly with the windpipe.

As with all other vertebrates the great oxygen-carriers of the whole

body-politic are the little red blood corpuscles; and it is interesting to note that, whereas in all mammals the immature corpuscles are nucleated, those of the full-grown corpuscles contain no visible nuclei. Again, with the exception of the Pigmy Musk Deer, the red blood corpuscles are fairly approximate in size, as is shown in the following Table, based to a great extent on the authority of the eminent hæmatologist, H. F. Nuttall:—

MEAN DIAMETERS IN MILLIONTHS OF AN INCH OF THE RED BLOOD CORPUSCLES OF THE WHALE AND OTHER REPRESENTATIVE ANIMALS.

| | Millionth Inch | | Millionth Inch |
|---|---|---|---|
| 1. Pigmy Musk Deer | 84 | 14. Orang Utan | 299 |
| 2. Nigerian Cow | 166 | 15. Man, European mean | 317 |
| 3. E. African Ox | 188 | 16. Camel | 325 |
| 4. E. African wild pig | 252 | 17. Whale | 327 |
| 5. Rhinoceros. (African) | 262 | 18. Ant-eater (African) | 367 |
| 6. Common Mouse | 266 | 19. Elephant (African) | 370 |
| 7. Wart hog (African) | 268 | 20. Manattee | 376 |
| 8. Vervet monkey (mean) | 279 | 21. Lamprey (fish) | 476 |
| 9. Man (European) min. | 280 | 22. Ostrich (Bird) | 616 |
| 10. Giraffe | 280 | 23. Frog (Amphibian) | 620 |
| 11. Baboon (Papio) | 281 | 24. Turtle (Reptile) | 824 |
| 12. Man (E. African) | 289 | 25. Amphiuma (Amphibian) | 2,790 |
| 13. Chimpanzee | 298 | | |

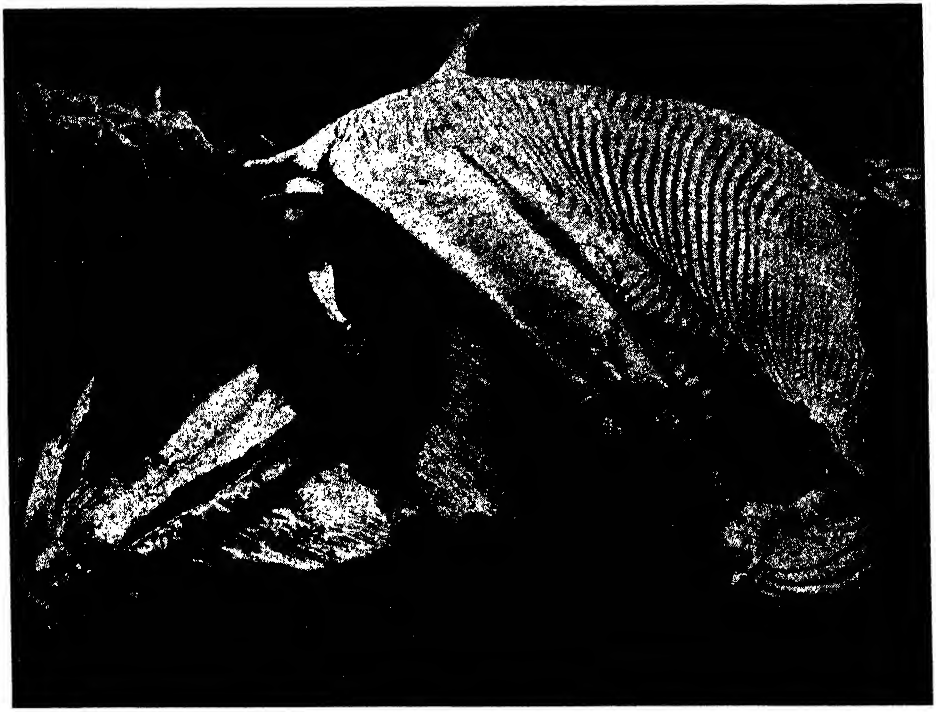
Whales are short-lived; twenty years ushers in old age. Parents are devoted to one another and to their offspring, a trait that unfortunately is exploited by hunters, who kill a young one knowing that the parents will return to the vicinity. As a rule only one is brought forth at a birth, though rarely twins are born. The young are remarkably precocious, and many can fend for themselves soon after birth. A new-born Dolphin is said to be able to keep up with a fast-swimming school. When only two years old, whales are sexually mature. To feed her young one the mother turns partly on her back to bring the udder out of the water; when the baby-whale seizes the teat the mother holds it up tightly pressed against her body by means of one of her "flippers." In this way the youngster's head is kept out of the water so that it can draw its nourishment without any interference with breathing. The milk-ducts open into large reservoirs at the hinder end of the body, and the contents of these are squeezed out into the mouth of the feeder so that the actual time of suckling is reduced to a minimum.

Whales have much to tell us about Evolution even before they are born. Hair is practically useless to prevent loss of heat from a body under water. For this reason these animals have shed their hair and have

substituted as their main heat insulator a layer of fat, or blubber, beneath the skin, which plays the part of an asbestos jacket to a boiler. The fœtus of the whale, however, is clothed in a hairy coat—a reminiscence of its hair-covered terrestrial ancestors. For some not clearly understood reason the fœtuses of the Narwhal and White Whale have lost even these vestigial hairs, a fact that at any rate bears evidence of the general trend of whales to a state of perfect nudity.

In embryo whales the pectoral fins, the modified front legs of terrestrial ancestors, are relatively larger than in adults. The hind limbs, to all intents and purposes, have disappeared, though in porpoises their supporting bony girdle, the pelvis, remains as a vestige. But certain of the great whales, such as the Sperm and Greenland, still carry, deep sunk in their hinder soft parts, the useless and cumbersome remains of legs. Occasionally whales show traces of pinnae, or external ears, but as a rule, conformably to streamlining, these have been eliminated; the ear apertures, leading to the drum, middle, and internal acoustic apparatus, are so contracted as scarce to admit a pencil even in the largest whale. So specialized have these huge mammals become to aquatic life that their hearing powers are better adapted to water than to air vibrations. As regards their organs of vision, too, they see better under, than out of, water, for in the air they are myopic, or short-sighted, in consequence of a modification of the curvature of the lens to make it better suited to under-water vision. Again, their eyeballs are rather rigid and fixed, so that rotation is restricted—a combination of effects traceable in part to the contraction of the front-to-back diameter of the skull that has gone hand in hand with its general rounding in shape. For a similar reason, possibly, the whale has been unable to imitate the achievement of certain fishes, which have so modified the lens and cornea that the upper half of the focussing mechanism is adapted to aerial vision, the lower half to water vision. Finally, stereoscopic vision in whales is very poor or altogether absent. The rudiments of a pineal eye are present in most whales, if we exclude the Dolphins.

The olfactory sense in Toothed Whales is poor, though the whalebone-bearing kind have managed to retain a well-developed olfactory nerve and a fair sense of smell. Bony plates are found in the skin of a few Dolphins—a condition that has led some biologists to postulate armour-plated ancestors. The Whalebone Whales are four-fingered; some of their digits actually support tiny rudiments of finger-nails. The teeth, again, of whales are of especial interest to Evolutionists. They are, needless to say, most in evidence in the toothed kinds, though absent from the upper



E.N.A.

FIG. 121.—A Fine Finback Whale.

The man seated in the whale's mouth demonstrates the great size of the animal. Note the creature's tongue (shown at the right) and the soft, hairy, and exceedingly flexible whalebone (left), which acts as a filter, allowing the water to escape but trapping everything else.

jaw of the Sperm Whale. The normal number of teeth in a placental mammal, in which category man and whale fall, is 44. Both these mammals, however, break away from the average, for man has thirty-two, and the whale a very varied number of teeth. In the round-headed Dolphin *Globicephalus*, or Ca'ing Whale, the number of teeth exceeds 100, and the Dolphin *inia* has over twice that number. At the other extreme is the male Narwhal, *Monodon*, whose murderous-looking single incisor tooth may be 8 feet long. This miscalled "tusk" or "horn" has an atrophied "opposite number" in the corresponding half of the jaw; in the female the tooth is diminutive. The Toothed Whales *Ziphius* and *Hyperoödon* possess one ordinary-sized tooth in each jaw, supplemented in the case of the latter whale by numerous very small functional teeth; *Ziphius*, too, has numerous tiny teeth, but they are functionless. Yet another dental characteristic of the Toothed Whales is the presence of the

rudiments of milk teeth—the normal state of affairs in land mammals; in which, however, they break the gums and have a temporary functional use. Whalebone Whales lack teeth altogether, except for vestiges in their embryos, and even these may vanish before birth, for they are but the useless relics of the once useful grinders, cutters, and tearers, of land ancestors. Their disappearance is an adaptation to the mode of feeding of this sub-order of whales which consists in sieving myriads of minute surface-swimming animalcules (Fig. 121).

The brain of Cetaceans deserves more than passing notice. The first things that strike one are its rounded shape and well-developed convolutions, the latter, relatively and absolutely, exceeding even those of ourselves. In actual weight the brain of a large whale would just about balance four human adult brains, but in proportion to body-weight the Cetacean brain may be as low as one to 30,000, in contrast to man's one to thirty-seven. In the two Tables below are shown some typical brain- to body-weight ratios, and some absolute brain-weights. They must be taken as approximations only since many of the items comprise great diversity.

Whales carry dorsal, pectoral, and caudal fins. Their forward movement, which is somewhat undulatory, like that of a slow-moving fish such as a trout, is effected by the tail fin, which, unlike the vertical organ of fishes, is horizontal. The uplifting of the whale's tail causes its head to rise; its depression lowers the head. The fore-limbs, or pectoral

TABLE SHOWING SOME BRAIN- TO BODY-WEIGHT RATIOS.

| | | | |
|---|---|---|---|
| 1. Blue Whale | 35,000 | 21. Bird (Av.) | 250 |
| 2. Whalebone Whale | 32,000 | 22. Gorilla | 200 |
| 3. African Elephant | 23,000 | 23. Mammal (Av.) | 180 |
| 4. Sperm Whale | 18,000 | 24. Cat | 160 |
| 5. Brontosaurus (Extinct) | 12,000 | 25. Insect (Max.) | 150 |
| 6. Porpoise (Min.) | 10,000 | 26. Rabbit | 140 |
| 7. Fish (Av.) | 5,500 | 27. Duck-mole | 130 |
| 8. Greenland Whale | 3,000 | 28. Porpoise (Max.) | 95 |
| 9. Insect (Min.) | 2,500 | 29. Weasel | 90 |
| 10. Reptile (Av.) | 1,300 | 30. Rat | 80 |
| 11. Giraffe | 900 | 31. Chimpanzee | 50 |
| 12. Ox (Av.) | 850 | 32. Man (Min.) | 40 |
| 13. Kangaroo | 800 | 33. Man (Max.) | 35 |
| 14. Rhinoceros (African) | 760 | 34. Field-mouse | 30 |
| 15. Wombat (Marsupial) | 614 | 35. Goldfinch | 25 |
| 16. Bear | 500 | 36. Human infant | 25 |
| 17. Elephant (Min.) | 500 | 37. Man (Birth) | 15 |
| 18. Horse | 400 | 38. Canary | 15 |
| 19. Sheep | 350 | 39. Blue tit | 12 |
| 20. Dog (Av.) | 300 | 40. Human fœtus | 10 |

TABLE OF ABSOLUTE BRAIN WEIGHTS.

| | Brain weight, lb. | Brain length, inch | Brain width, inch |
|---|---|---|---|
| 1. Sperm Whale | 15·40 | 9·20 | 11·81 |
| 2. Whalebone Whale | 13·10 | — | — |
| 3. Blue Whale | 7·00 | — | — |
| 4. Elephant | 6·40 | — | — |
| 5. William Makepeace Thackeray | 3·60 | — | — |
| 6. Eminent Irish F.R.S. | 3·41 | — | 0 |
| 7. Mean of 25 University Professors | 3·18 | 7·42 | 5·71 |
| 8. Neolithic Man | 3·14 | — | — |
| 9. Mean of 37 Naval Artificers | 3·06 | 7·38 | 5·65 |
| 10. European Man (Av.) | 2·95 | 6·76 | 5·16 |
| 11. Neanderthal Man | 2·69 | — | — |
| 12. Australian aborigine (Max.) | 2·415 | — | — |
| 13. Piltdown Man | 2·37 | — | — |
| 14. Australian aborigine (Mean) | 2·362 | — | — |
| 15. Australian aborigine (Min.) | 2·310 | — | — |
| 16. Anatole France | 2·24 | — | — |
| 17. Pithecanthropus erectus | 1·89 | — | — |
| 18. Gorilla (Max.) | 1·320 | — | — |
| 19. Gorilla (Mean) | 1·285 | — | — |
| 20. Gorilla (Min.) | 1·250 | — | — |
| 21. Chimpanzee (Mean) | 0·946 | — | — |
| 22. Orang-Utan (Mean) | 0·894 | — | — |

The Table shows Brain Weights of Whales as compared with those of Man, Elephant, Ape-Man, and Great Apes; also the Length and Width of Brain of Whale and of Man.

No. 7 is the mean of measurements of the brain calculated from measurements of the living heads of twenty-five university professors made by the anthropologist Dr. Alice Lee. No. 9 consists of similar measurements and calculations taken by the writer on thirty-seven naval artificers averaging twenty years of age. Nos. 8, 11, 13, 17 are based on measurements of the skull. Nos. 5, 6, 10, 12, 14, 15 are also from measurements of the living head. No. 16, the brain of a great writer, is described by Sir Arthur Keith, F.R.S., as "primitive." The formulæ used in calculating brain weights of living persons are those of Dr. Alice Lee, where W. = weight in grams, L., B. and H. respectively the length, breadth and height of the head in millimetres.

For males. $W. = 0{\cdot}000337\ 11 \times L. - 11 \times B. - 11 \times H. - 11 + 406{\cdot}01$

For females. $W. = 0{\cdot}000400 \times L. - 11 \times B. - 11 \times H. - 11 + 206{\cdot}60$

fins, have many uses: they enable the animal to turn to right or left; they correct the tendency of the propeller-like action of the tail-fin to rotate the body as a whole about its long axis; they act as balancers, and are used as "claspers" in mating; and in the female, they—or rather one of them—help to support the little one while it is suckling.

To give additional buoyancy to these monsters of the seas—the largest the world has seen—their bones are infiltrated with oil; the spermaceti oil is located in hollows in the skull of *Physeter macrocephalys*, the Sperm Whale. This oil is refined to form the familiar pearly-white wax of which the better-class candles are made. The oil obtained from the forehead of *Hyperoödon*, the Bottle-nosed Dolphin, is so clear and limpid that it is

in great request as a lubricant for chronometers and delicate machinery. The situation and relative proportion of oil in the body of the Great Whales have a practical bearing for whale-hunters, for whereas the dead bodies of the Greenland, Bowhead, and Sperm Whales float on the surface of the sea, those of the Blue, Sei, Finback, and Humpback Whales sink. Other coveted products of whales are ambergris and whalebone. The former is a pathological concretion in the intestines, and is used as an ingredient of perfumes; its pre-war value was £8,500 per ton. Baleen, or whalebone, is a horny production of the lining tissues of the mouth and palate, the hypertrophied transverse ridges normally present on the palates of most mammals, including ourselves; in the whale it forms the scaffolding supporting 370 blades, some of which are over a dozen feet long. As the whale leisurely swims along the surface of the sea with its mouth wide open, myriads of tiny molluscs, crustaceans, and other small organisms, are caught on the sieve; the tongue then forces the water out of the mouth, leaving the "brit"—as the *Omnium gatherum* of food is called—sticking on the sieve, to be swallowed at leisure. Before the war the value of whalebone was £2,000 a ton.

Whales, for the most part, are sociable and affectionate creatures, living, feeding, hunting, and playing together in herds. Their cry is not unlike that of a cow; though, as we have seen, their nearest relative is probably the pig. The *Orca*, or Killer Whale, is one of the most ferocious creatures of the seas. It readily attacks man, will try to shake him off an ice floe so that it can get at him, and at times it turns into a cannibalistic epicure, for a pack will make a concerted onslaught upon a large whale and, having literally battered the poor animal into a state of exhaustion, will tear the tongue out of its mouth and devour it piecemeal, leaving their mutilated victim to die by inches on the surface of the sea. But the whale's worst enemy is undoubtedly man. He slays it wholesale for the purpose of converting its blubber into oil, its spermaceti into candles, its hide into bootlaces, and its carcass into fertilizers. In 1925–1926, in the Falkland Island Dependencies alone, 13,188 whales were slaughtered, from which 722,537 barrels of oil were extracted—an average of fifty-five barrels per whale. In 1937–1938, in the whole world, 46,039 whales were slain, consisting of 14,923 Blue, 28,009 Finback, 2,079 Humpback, 867 Sperm, and 161 Sei Whales. One 89 ft. long Blue Whale, weighing 119 tons, yielded 166 barrels of oil. Such figures alone suffice to indicate that these noble, sensitive, helpless creatures, high up in the scale of evolution, will need a great deal more organized protection from their fellow-mammal, man, if they are to be prevented from going the way of

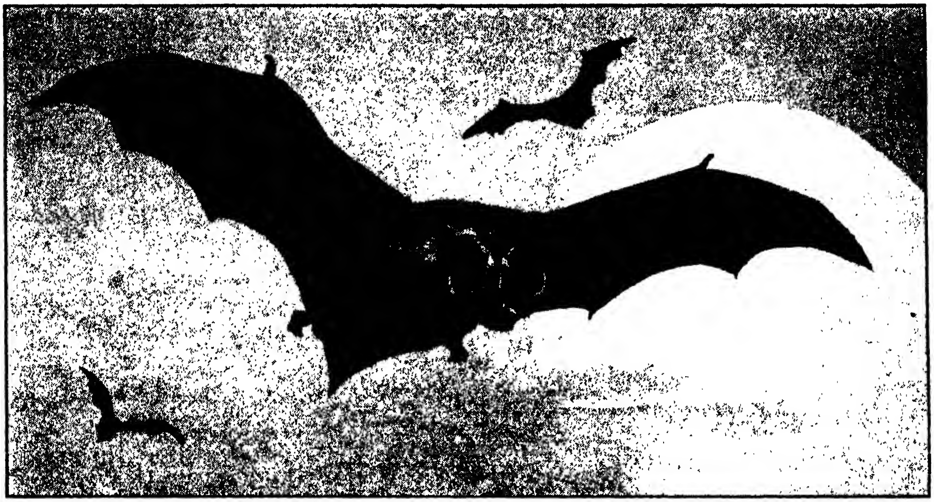


FIG. 122.—A Flying Mammal—the Bat.

Bats belong to the order Chiroptera. They are mostly nocturnal in habit, and vary in size from our common little "flitter-mouse" to *Pteropus*, or the Fox-Bat, which measures 5 feet across the extended wings. They are insect-eating and fruit-eating, though at least one—the vampire *Desmodus*—is blood-sucking. The wing, or patagium, is spread over the five fingers of the fore-limb, thence to the hind leg, but leaving the five-clawed toes free; from the leg it extends to the tail. The thumb is clawed. Bats appear first in the lower Eocene period.

the giant Moa of New Zealand, the Aepyornis of Madagascar, and the Dodo of Mauritius.

Another animal in the Class Mammals is the bat. Fig. 122 shows one in full flight with its membranous wings extended. There are many families found all over the world, and one family, the Vespertilionidæ, contains over 190 species. Bats probably constitute a line of mammals that branched off from the main stem in late Cretaceous and early Eocene days.

The Insectivora, so called because they feed on insects, are in the main line of the mammals. Fig. 123 shows three common but interesting types. The small animal at the top is the shrew (*Sorex*), often called a shrew-mouse, although it is not really a mouse, being more akin to the mole. Shrews are a very old family, and very widely spread; one of them, *Sorex minutus*, is the smallest British mammal. The animal in the middle is the common mole (*Talpa Europæa*). It is found only in the Old World, though there are mole-like creatures in America. The bottom animal is the hedgehog (*Erinaceus*). It not only eats insects and slugs, but also chickens, young game birds, and vipers. These three

creatures are among the most interesting of English animals because of their enormous antiquity, and because they give us a hint of the kind of small ancestral mammals from which all modern ones, including mankind, have sprung.

Fig. 124 shows a water-shrew, which is larger than the common English shrew. They are not "true shrews," but belong to a family connecting these with the moles.

The remarkable animal shown in Fig. 125 has been classed, now as a lemur and again as a bat; and yet again it has been placed all by itself in a special order of mammals. Dr. Beddard says: "It is better to regard it as an aberrant Insectivore—so different indeed from other forms that it requires a special sub-order for its reception." It is larger than any other Insectivore, being about the size of a cat. *Galeopithecus volans*, as this creature is called, inhabits the Oriental region. It has a remarkable fold of skin, the

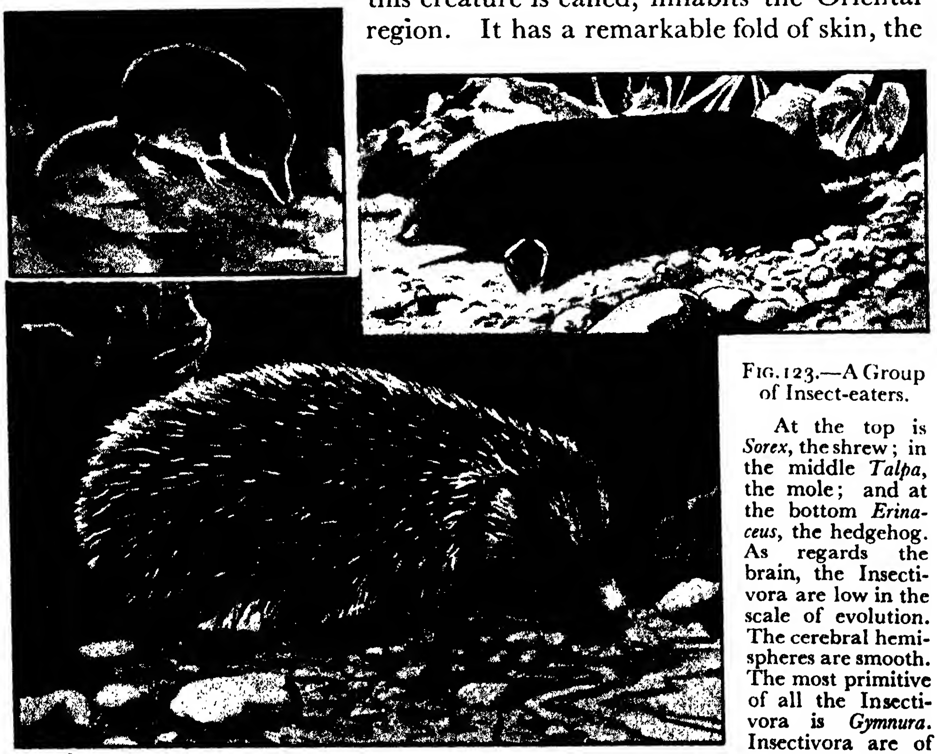


FIG. 123.—A Group of Insect-eaters.

At the top is *Sorex*, the shrew; in the middle *Talpa*, the mole; and at the bottom *Erinaceus*, the hedgehog. As regards the brain, the Insectivora are low in the scale of evolution. The cerebral hemispheres are smooth. The most primitive of all the Insectivora is *Gymnura*. Insectivora are of particular interest to zoologists, for it is believed that it is from a generalized form of their stock (a sort of hybrid between a lemur and a mongoose), at the dawn of the Tertiary, that the common ancestor of the carnivora and the Primates arose.

patagium, which extends from the neck to the fore-limb, and thence to the hind-limb and tail, by means of which it is able to fly. This membranous fold is midway between that of the flying-squirrel and the bat. In this and other ways Galeopithecus is a real connecting-link—a sort of composite animal holding affinities with bats, flying-squirrels, and lemurs.

FIG. 124.—A Water-Shrew.

A link between the true land shrews and the moles. W. D. Matthew regards the primitive early stock of Insectivora as our distant ancestors in basal Tertiary days. The most primitive living representative of insectivores is *Gymnura*, an insect-eating animal of Malay not unlike the water-shrew depicted above.

Shipley and MacBride say: "The most interesting circumstance about

FIG. 125.—*Galæopithecus volans.*

An aberrant Insectivore. It inhabits Borneo, Sumatra and Malay. It is a very skilled glider, and can vol-plane for 70 yards, with a drop of only 1 in 5. This curious creature is the sole representative of the sub-order *Dermoptera*. The patagium extends from the side of the neck to the tip of the tail; and even the digits are all webbed. When sleeping, the animal hangs upside down. It bears two breasts in the pectoral region and gives birth to only one at a time.

FIG. 126.—Ring-tailed Lemur.

the Insectivores is the fact that when, by means of fossils, we trace back the higher groups of mammals, they *all* seem to merge imperceptibly into Insectivores—*i.e.*, the *primitive* insect-eaters.

"There is really good ground for supposing that the living Insectivores, though modified in special details, nevertheless represent, so far as their general organization is concerned, the earliest type of Eutheria which appeared on the globe. From these original Insectivores advance seems to have taken place along five lines:—

"I. Some Insectivores took to attacking larger prey, including their own less fortunate relations, and gradually developed into the Carnivora, or flesh-eating mammals. These are tigers, cats, dogs, wolves, etc.

FIG. 127.—Black Lemur.

The Lemurs are of great interest as forming the link between the *Anthropoidea,* or monkeys, and the lower mammals. They possess an opposable thumb and great toe. As a rule their mammæ are pectoral. Their brain is but poorly convoluted and bears a Simian fissure. The second toe has a pointed claw, but as a rule the other digits bear flattened nails. Some few, in addition to the pectoral breasts, bear abdominal and inguinal ones.

"II. Some became vegetable feeders, and gave rise to the great group of hoofed animals, relying either on their swiftness, or size, or strength for defence. These are horses, cows, elephants, etc.

"III. Some took to burrowing, and developed into gnawers or Rodents, relying chiefly on their holes for safety. These are rabbits, rats, mice, squirrels, etc.

"IV. Some took to the air, the fore-limb becoming changed into a wing. These are the bats.

"V. The remainder took to escaping into trees when hard pressed, and eventually gave rise to the great group of the Primates, which includes monkeys, apes, and man."

Leaving the first four groups as side lines of Evolution, we will devote our attention to the Order Primates, a name meaning "first" or "highest." All zoologists now agree that lemurs, monkeys, and man must be classed in the same Order—a fact which in itself is a remarkable testimony to the truth of the evolution of man.

The Primates are divided into two suborders:—

(1) Lemuroidea, or lemur-like animals.

(2) Anthropoidea, or man-like animals.

FIG. 128.—*Chiromys*—the Aye-aye.

This Madagascan Lemur is of a highly-specialized type. It possesses a very long thin third finger. The digits are clawed except the thumb, which bears a flat nail. The breasts are borne in the groin.

FIG. 129.—An Adult Female *Tarsius spectrum*.

Tarsius is placed in a sub-order (II) by itself. It is a link between the lemurs and anthropoids. Its ancestral stock was probably the common progenitor of the lemurs, monkeys, apes, ape-men, and the various human branches. As might be expected from its enormous eyes, the visual brain centres predominate over olfactory brain centres.

There are three families and four sub-families of lemurs. In Latin, *lemures* means the ghosts or spirits of the dead, and as these animals come out mostly in the night, and are silent, mysterious, and ghost-like in their movements, Linnæus named them "lemurs." The Indris, found only in Madagascar, has much larger legs than arms; the ears are short, the tail varies in length, the thumb is but slightly opposable, and the toes are webbed. When it walks on the ground it does so on its hind limbs, holding its arms above the head. The ring-tailed lemur (Fig. 126) has flat, human-like nails on all its fingers except the forefinger.

Fig. 127 shows a mother lemur with her little one lying across her belly. The young one is often carried in this way by the mother; its tail passes round her back, and then round its own neck. It has been suggested that this instinct came from ancestors which used to carry their young in a pouch, after the fashion of marsupials (Fig. 117).

The Lemuroids are the most ancient of the Primates. The Aye-aye (Fig. 128) and *Tarsius spectrum* (Fig. 129) are the living relics of far-back

FIG. 130.—Slender Loris.

The *Lorisidæ* constitute the fifth family of the lemurs. They are nocturnal in their habits, are tailless, and occupy Africa and Asia.

ancestors whose fossils have been found in the Eocene of N. America and Europe. Professor Wood-Jones believes that Tarsius, the quaint little wide-eyed nocturnal tree-lemuroid of Java, Borneo, the Philippines and adjacent islands, is a nearer relation of man than is the ape; that is, that man is in the direct line with the Eocene *tarsioids*. Sir Arthur Keith's, and probably the more prevalent, view is that man *and* ape evolved from a common tarsioid stock which, commencing in the Eocene period, gave off a series of branches in the following order: Lemurs, Monkeys of the New World, Monkeys of the Old World, small Anthropoid Apes, large Anthropoid Apes, Pithecanthropus, Peking Man, Neanderthaloids, Piltdown and Rhodesian Man, and, finally, modern races of men. Yet another view, which would appear to have received the support of Professor Elliot Smith, is that, in the upper Cretaceous, primitive mammals of the jumping-shrew type became the tree-climbing, insect-feeding shrews from which arose the Tarsiodea. From these evolved, in the Eocene, first the New World, and later the Old World, Monkeys. In the Oligocene there arose from the latter the ancestral representatives of the Anthropoid Apes. These, continuing their evolution through the Miocene and all the while throwing off several side-branches, gave off in the late Pliocene and subsequent periods a series of branches representing

the extinct and surviving races of man (see Fig. 18, Chap. I). The Aye-aye (Fig. 128) hails from Madagascar and is a most remarkable animal. Its bushy tail and long incisor teeth are like those of a squirrel. There is one pair of abdominal teats in the female; the third finger is much longer than the others and very thin, while the thumb and big toe have *flat* nails. All the other digits have claws. It is believed to thrust its long middle finger into holes and crevices in trees, and with it to ascertain the presence or otherwise of grubs, and especially the fat larvæ of a certain wood-boring beetle to which it is very partial. Once discovered, the food is extracted with the help of the chisel-shaped teeth. Mr. Bartlett has, however, seen this creature use the slender and specialized digit for "combing out its hair, and for other purposes of the 'toilet.'"

The Aye-aye is a mosaic-like animal possessing affinities with many groups. Its incisor teeth are unlike those of lemurs, being more of the rodent type, and there are no canines. There are many superstitions about it among the natives, who so reverence it that they never molest it, and bury carefully any specimen found dead. Another species of lemur, the Loris, is confined to India, Ceylon and parts of Africa. In Fig. 130 it is shown awake and active, and also resting.

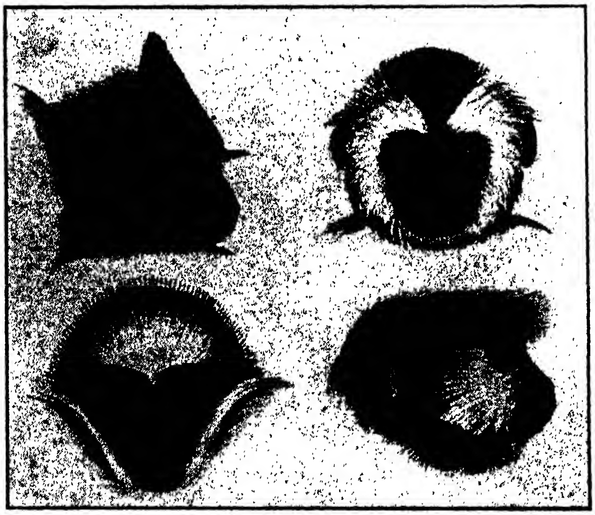


FIG. 131.—Representations of both Sections of the Man-like Monkeys.

The *Platyrrhini*, or broad-nosed (bottom left and top right), and the *Catarrhini*, or narrow-nosed (top left and bottom right). In the Platyrrhines the tail is long and often prehensile. They have no cheek-pouches. They inhabit the New World, and include the Marmosets, the Howling Monkeys, and Spider Monkeys. The Catarrhines have a short tail or no tail; cheek pouches are the rule. They belong to the Old World, and include the Baboons, Mandrill, the Sacred Indian monkey, and the Proboscis monkey of Borneo.

The Anthropoidea, or man-like animals, include monkeys, apes, and man. There are 212 species, all contained within two groups—the Platyrrhines (flat-nosed) and the Catarrhines (down- or narrow-nosed).

In Fig. 131 the top monkey on the left, and the bottom one on the

right, are Catarrhines; the other two are Platyrrhines. Observe that in the former the nostrils are narrower and look downwards, whereas in the latter they are broader and turned slightly outwards. The picture also shows the odd arrangement and development of the hair on the head. Flat-nosed monkeys are found only in America, while the down-nosed ones are found only in Europe, Asia, and Africa. The two groups have probably been distinct since

FIG. 132.—Marmosets.

The marmosets are the smallest of the monkeys, not much larger than squirrels. They are a Family (*Hapilidæ*) of the Platyrrhines. The shell of the ear is very hairy; the long bushy tail is not prehensile. They often bear three young at a birth; most monkeys bear only one.

the Eocene period, as no fossil remains of intermediate forms between them have yet been discovered. That two groups of animals should have arisen in the far-distant past, and each developed on its own line, never to meet the other again, is an amazing fact.

We will consider the flat-nosed American monkeys first, for they stand

near the base of the whole series, and show the connection between lemurs and monkeys. This is another example of the existence of very ancient creatures in South America. *Remember the flat-nosed monkeys are not in the direct line of man's ancestors, but in a side line.* Nevertheless, they are of great interest in that they show some of the common features of the common ancestors. Marmosets, of which there are two genera and some 21 species, belong to the lowest family of monkeys (Fig. 132). In them the fingers and toes are, for the most part, *clawed*, only the great toe bearing a flat nail, and the tail is ringed—a feature often found in lower mammals but not in higher apes. The Cebidæ, or long-tailed monkeys, are also peculiar to America. In Fig. 133 the one on the right is the spider-monkey, clinging to a branch with his tail; that at the bottom on the left, with the sad poetic expression, is the red-faced ouakari. The third one, top left, is the white-nosed saki.

These monkeys, of which there are five species, have long bushy tails, are bearded, and possess a thumb. One species of saki uses its hand to drink instead of putting its mouth to the water, as the other species do.

The squirrel monkeys (Fig. 134) are small creatures, with long heads and short thumbs. They are remarkable for the size of their heads, which, in proportion to their faces, is greater not only than in other monkeys, but than in man himself. Humboldt asserted of one of them that, when vexed, its eyes filled with tears.

Fig. 135 shows five skulls. At the top, beginning from the left, we see the human skull, and on the right that of the woolly monkey (Lagothrix), one of the most human-looking skulls found outside the human family. At the bottom the skull of the macaque, one of the largest of the Asiatic monkeys, is shown on the left; that of the gorilla in the middle; and a baboon's on the right. They all look somewhat dog-like because of the projection of their jaws, which becomes yet more marked with increasing age.

The Catarrhines, or down-nosed apes, are of remarkable interest to us, as they are *near blood relatives.* They are divided into three families: (1) The tailed apes (Cercopithecidæ); (2) The Anthropoid, or man-like apes (Simiidæ), which have no tails; and (3) The Hominidæ (Man).

Under (1), the Cercopithecidæ we will notice three kinds.

The Tcheli monkey (Fig. 136, top left) is striking in many points—its dog-like body, its short tail, its baby-like hands, and its John-Bull expression. It is found in North China, and, like the tiger of the same region, has an extra thick fur to enable it to bear the bitter winters. The Diana monkey (Fig. 136, bottom left) is a genus limited to Africa.

It has quite a respectable professional air, with its fine white beard and aquiline nose. The Entellus, also shown in Fig. 136, is one of the sacred apes of India.

Passing to the second family (the Simiidæ), we come to the anthropoid or man-like apes. They differ from the former in but few points, yet have moved in the direction of the human form. "In this family the tail is completely absent, the arms are longer than the legs, and the gait might be described as that of a baby learning to walk. They never go completely on all-fours, but usually shuffle along unsteadily on their two feet, which, like those of a baby, show a tendency to turn inwards under them, Figs. 141, 149; they usually steady themselves either by means of a stick or by bending forward so that their knuckles touch the ground" (Shipley and MacBride, Figs. 138, 139, 140).

Dr. Beddard indicates some of the points in which this family of man-like apes resembles man, thus: "Though they live in trees for the most part, yet when on the ground they progress in a semi-erect fashion. When they put their hands on the ground to aid them in walking, they do not rest, as do the lower apes, on the flat of the hand, but upon the back of the fingers. The hand, in fact, is growing less like a foot in its use."

None of the Simiidæ has a tail or cheek pouches. The

FIG. 133.—A Group of Cebidæ.

A family of the Platyrrhine monkeys. They have, as a rule, long, prehensile tails, well shown in the picture of the Spider-monkey on the extreme right. (Top centre): the Saki or Pithecia. (Bottom): the red-faced Ouakari.

FIG. 134.—The Squirrel Monkey.
The head bears a larger ratio to the face than that even of Man.

hair is rather more scanty than in the former family. The placenta, or after-birth, differs in detail from that of the lower apes, and is exactly like that of man.

Their arms have a greater length as compared with their legs than the family below them. The Simiidæ are divided into four groups: Gibbons, Gorillas, Chimpanzees, and Orangs.

The gibbons (Fig. 137), which range through S.E. Asia, are the smallest existing anthropoid apes; and they are the most truly tree-frequenting of all this family—hence their very long arms. So agile are they in the forest that they can take leaps from branch to branch of 18 to 20 feet. In the

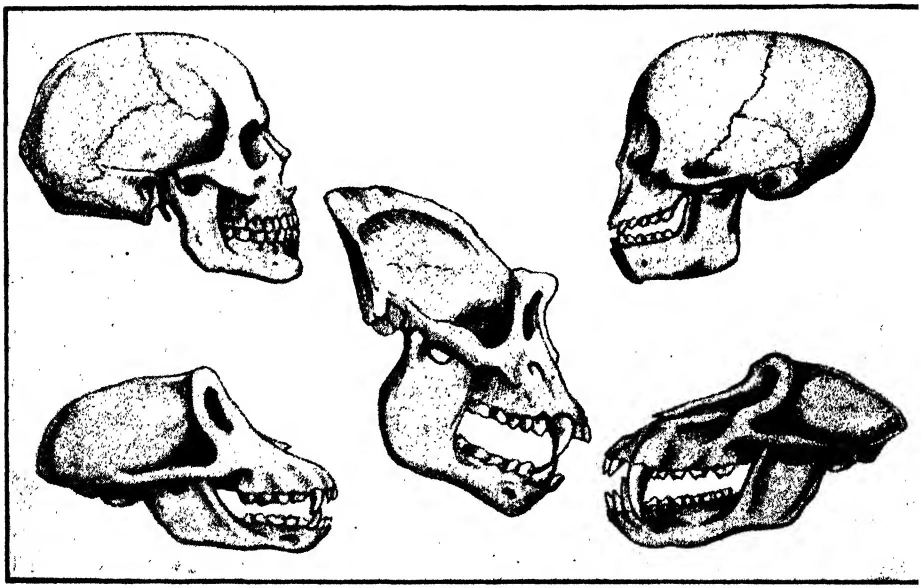


FIG. 135.—Skulls of Monkeys and Man.

**Reading from left to right and from above downwards: Human skull; skull of woolly monkey—a remarkably human-like skull; skull of Macaque, one of the Catarrhines; skull of gorilla, a man-like ape or anthropoid; skull of dog-faced baboon (*Cynomorpha*), a Family of the Catarrhines.**

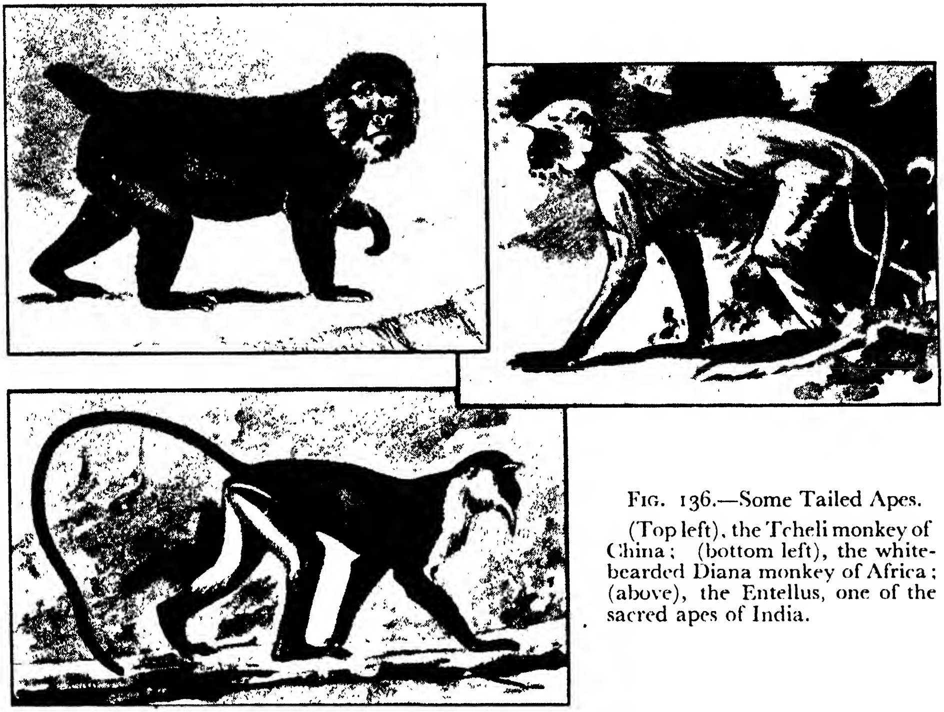


FIG. 136.—Some Tailed Apes.

(Top left), the Tcheli monkey of China; (bottom left), the white-bearded Diana monkey of Africa; (above), the Entellus, one of the sacred apes of India.

FIG. 137.—The Hoolock, one of the Gibbons, of the Family Simiidæ.

The gibbons frequent the Malay peninsula. On the ground they walk upright, but are most at home in the trees. They are about 3 feet tall, possess thirteen ribs on each side, and have flat nails on the thumb and great toe. The gibbons are closest to man in the structure and arrangement of the teeth. Like other Primates, they are tailless.

They have a powerful voice with a remarkable range of notes. One of them, the *Siamang*, has a laryngeal sac.

FIG. 138.—Gorilla.

The gorilla can walk upright with a very shuffling gait, but normally it walks, as depicted above, with the backs of its half-closed hands on the ground. Gorillas possess thirteen ribs on each side, and, of all the man-like apes, most closely approach man in their hands and feet, though the great toe is still well separated from the other toes (see Fig. 139), to form a branch-grasper. The gorilla is in a transitional state between an arboreal and terrestrial animal. It makes nests in the lower limbs of the forest trees to accommodate the females and young. The head of the family sleeps on the ground at the base of the tree.

midst of one such prodigious leap a gibbon was seen to catch a flying bird with one hand and attain the branch with the other; then, assuming a sitting posture, it "instantly bit off the head of the bird, picked its feathers, and then threw it down." When on the ground the gibbons walk erect with the big toes separated, as they are in man when the toes are not cramped by wearing boots. They drink in two ways: either by stooping and sucking up the water, or by scooping it up in the hand. The Siamang gibbon invariably lifts the water up to its mouth by dipping in its half-closed hand and then licking the drops off its fingers. Beddard describes the gorilla (Figs. 138 and 139) thus: "The face is naked and black; the skin generally is deep black, even at birth. The ear is small; it is more human in form than that of the chimpanzee. The nose has a median ridge; the nostrils are very wide. The hands and feet are short, thick, and broad; and the heel is more apparent than in the other higher apes. This is associated with his mode of walking on a flat foot. It is interesting to find that the muscles of the little toe are diminishing in the gorilla as in man; this is evidently due to leaving trees and walking on the ground, and not to tight boots. In fact, owing to his more erect gait—for he can readily assume the upright posture—many of his muscles are more like those of man."

The gorilla is found only in the forest tract of the Gaboon, Equatorial Africa. It goes about in families, with but *one* adult male, who later has to dispute his position as leader of the band with another male, whom

FIG. 139.—Male Giant Gorilla.

Gorillas are the largest and heaviest of all the Primates, including man. Height seldom exceeds $5\frac{1}{2}$ ft., but the weight may amount to 420 lb. They are denizens of equatorial Africa, and wander about in families.

he kills or drives away, or by whom he is killed or driven away. This anthropoid is the largest of all the apes.

The chimpanzee (Fig. 140) is also an African animal and in many points resembles the gorilla.

In mental characteristics, however, there is the widest difference between these two apes. The chimpanzee is lively and teachable, but the gorilla is gloomy, ferocious, and almost untamable. Both gorilla and chimpanzee drink by stooping and putting the mouth to water and sucking it up. In captivity, however, they can be taught, especially the chimpanzee, to lift a glass of water to the mouth and drink like a man.

Our last division of these interesting cousins of ours is the orang-utan of Borneo and Sumatra (Fig. 141). It is a large, heavy, pot-bellied ape, with a melancholy expression. The ears, small and not ungraceful, are

FIG. 140.—Female Chimpanzee (*Anthropopithecus Troglodytes*).

Like the gorilla, the chimpanzee can walk for a short spell, and somewhat unsteadily, in the upright position, though it, too, prefers to walk on the knuckles of its half-closed hands. When running, however, its gait is purely quadrupedal. It is more arboreal than the gorilla, lives in families, and makes nests in trees. They more closely resemble man than other apes in their intelligence and in the curves of their spinal column.

FIG. 141.—Orang-Utan (*Simia Satyrus*).

The arms of the orang are exceptionally long — sometimes 7½ feet long. Orangs inhabit the swamps and forests of Borneo and Sumatra, living and sleeping in the trees by day, coming down to the ground to feed by night. They make nests in the trees. The hair of the orang is reddish ; the gait is quadrupedal. They are very intelligent, but morose and sulky in late life. Sexual maturity is attained at six years of age. C. W. Beebe says that young orangs, in their "talk" and behaviour, are very like human infants. "The scream of frantic rage when a banana is offered and jerked away, the wheedling tone when the animal wishes to be comforted . . . the sound of perfect contentment and happiness when petted . . . all are almost indistinguishable from like utterances of a human child."

pressed closely to the sides of the head. The arms are so long that, when the animal is standing, they reach as far as the ankle. The big toe is very short, and usually without a nail. It is important to note the human look in the young head because, in the adult, this is much less marked, owing to the pushing forward of the lower jaw and its great increase in size. Sir Arthur Keith emphasizes the great interest of this point, for it indicates that modern man has gained his distinctive facial characteristics by carrying on into adult life certain skull features which are present in apes only during infancy. This ape lives mainly in the trees, amid the branches of which it constructs a new nest for itself every other night or so; and it drinks by dipping its hand into water and then licking the fingers, but when very thirsty it scoops up water and dribbles it off the hand into its upturned trough-like lips.

Upon carefully studying the skeletons in Fig. 142, few people would doubt that they are all rightly placed in one Order—unless you told them first that one of the skeletons was that of man!

Most of us are now familiar with the intelligent acts performed by monkeys and apes. Natives have trained them to climb coco-nut palms and to select and throw down only the ripe fruit. A baboon in

Africa was taught to manipulate correctly the levers in a railway signal box that controlled the shunting points of the lines.

Before leaving the man-like apes, or *Simiidæ*, it will be appropriate to reproduce a remark of R. S. Lull, Professor of vertebrate palæontology at Yale University. The Simiidæ—which it will be remembered comprise the gibbon, gorilla, chimpanzee and orang-utan—" of all creatures come nearest to mankind, not only in similarity of structure, but in actual relationship, for they are our next of kin in that they and humanity spring without question from the same bough of the tree of life, and though the relationship is very remote according to human standards of consanguinity, from the evolutionary point of view it is very close. This does not mean that man arose from any known ape, or that any ape could ever in the course of evolution give rise to a man, but that man and the ape had at some not very remote time, geologically speaking, a common ancestor."

Let us now look at a few primitive types of human beings.

Observe, in the boy in Fig. 143 and in the woman in Fig. 144, the

FIG. 142.—Skeletons of Gibbon, Orang, Chimpanzee, Gorilla, and Man.

Here are shown the skeletons of two families; the Family Simiidæ includes the Anthropoid Apes; the Family *Hominidæ* includes only *Man, Homo Sapiens*. The bones in these five skeletons are almost, though not quite, identical. The physical structure of man goes back to a very remote ancestry; his physiological activities to an ancestry less distant; his psychical capacities to an ancestry relatively proximate.

backward-sloping head and the projecting lower jaw and mouth, both ape-like features.

FIG. 143.—A Galla Boy, nine years of age.

Fig. 145 shows a group of natives from the Lake Chad district of Central Africa. In these the ape-like forward projection of the upper lip has been magnified by the adoption of a mouth "ornament."

Before being ashamed of our simian ancestry we ought to study the lower races of men. We should then find that the degrees of differences, mental and physical, between the highest apes and the lowest men are by no means very great. "Some animals have more intelligence than some men," writes Dr. Hornaday, "and some have better morals. I would rather descend from a clean, capable and bright-minded genus of apes than from any unclean, ignorant, and repulsive race of the genus *Homo*. . . . There are millions of members of the human race who are more loathsome and repulsive than wild apes."

The family *Hominidæ* contains only one genus, *Homo*, and one species, *Homo sapiens*, which is divided up into the following varieties. In this division I have taken as my authority R. S. Lull, as quoted in his work *Organic Evolution.*

1. *Australian variety.*—Australia, Dekkan, Hindustan. Long-headed. Chocolate-coloured skin; black, long woolly hair; long-limbed.

2. *Negroid variety.*—Madagascar and Africa from the Sahara to the Cape of Good Hope. Long-headed. Flat nose; prognathous; black skin; black, short, woolly hair.

FIG. 144.—A Hottentot Chief and his Wife.

3. *Mongolian variety.*—Habitat: East of a line drawn from Lapland to Siam. Chinese, Tartars, Japanese, Malays, Esquimaux, N. and S. American natives. Short-headed. Flat-nosed; oblique eyes; golden-brown skin; sleek, coarse, black hair; scanty beard.

FIG. 145.—A Group of Natives from the Lake Chad Region of French Equatorial Africa.

4. *Caucasian variety.* Europe, N. America, Egypt, Persia, Turkey, Armenia.

(A) Mediterranean. Long-headed. Dark brown to black hair and eyes.

(B) Alpine. Western Europe and North America; includes also Moors, Berbers, Egyptians, Kurds, Persians, Afghans, Hindus, Turks, Armenians, Afrikanders and none-native Australians. Round-headed. Dark brown to black hair and eyes.

(C) Nordic. Tall, long-headed. Flaxen, red, light-brown or chestnut hair; blue, grey or green eyes. Mainly Europe and N. America. Includes Moors, Berbers, Egyptians, Kurds, Persians, Afghans, Hindus, Turks, Armenians, Afrikanders, Australian aborigines.

# CHAPTER SIX: AN OUTLINE OF THE LAWS OF EVOLUTION

IN astronomy we saw that heavenly bodies had evolved, and are still evolving, by the condensing of the lightest known gaseous substance. Coming to the earth, we saw that its upper crust has been slowly formed, layer upon layer, as a result of cooling. In these layers of rocks we read the tale of life. Beginning at the lowest depths of stratified rocks, we found the remains of animals —but not of the same kind as those now around us. The fossils of that early period tell the story of species that have disappeared. As we come nearer the present surface of the earth, and therefore nearer to modern times, we are impressed by the change which millions of years have produced; the rocks show us fossils more and more like the living things of to-day, till, in the topmost rocks, we find that the animals of a few thousand years ago so closely resembled our own that they can be arranged in the same groups. This shows us that changes from the earliest animals to those of our own time are gradual and connected; it proves that the simple, small forms came first in the world's history, and that, just as the bicycle has gone on improving, so the low forms of animals died out, their place being taken by better forms which had sprung from them by slow changes in advantageous directions. This extinction of so many animal groups is perhaps one of the most astounding and terrible lessons which the rocks teach us.

Further, we have seen in looking at living animals that, if we begin with small creatures which are merely *one* cell of jelly-like matter, we can trace the path of evolution from them up to man, not by a single step, but by multitudes of steps. We have seen that there is no hard-and-fast line betwixt two adjacent groups, since animals occur which are partly like a group below them and partly like a group above.

We saw that a piano and a rifle are the outcome of the bow and arrow. Some of the principles upon which a piano and a rifle are constructed occur in the bow and arrow, though they are somewhat mixed and undeveloped. The bow and arrow in this sense are "generalized"; but after many years of improvements on two quite distinct lines we see two highly specialized instruments—one for producing pleasure in the form of music, the other for causing pain and death—so unlike one another that few people suspect they have had a common origin. This has


1. Blue Turbit. 2. Magpie. 3. Norwich Cropper. 4. Black Nun. 5. Short-faced Almond Tumbler. 6. African Owl. 7. Trumpeter. 8. Jacobin. 9. Fan-tail. 10. Black Carrier. 11. Blue Rock. 12. Blue Pouter.

happened in the few years known to history; what, then, may not have taken place in the evolution of *living* things in millions of years?

In trying to grasp the great principles of Evolution we should look at the more primitive animals and note the points they have in common with the next higher group, and also any new points that have appeared in the latter. Thus we form a ladder, and mount step by step to civilized man.

Again, we should examine the several parts of the human body and trace them back to their origin. For instance, the backbone is common to the human race and to all animals above and including the fishes, but we know there was a time before the advent of fishes when no animal had a backbone. Therefore, we assume that all these backboned animals have come from the same group of backboneless ancestors. Then, when we come to examine the various creatures lying, so to speak, in a sort of " no-man's-land "—neutral territory, between the lowest animals with, and the highest animals without, a backbone—we are provided with ample indications of the manner in which so very definite a structure first arose.

Consider the twenty digits, or the four limbs, or the two eyes, or the brain, or, in fact, any other structures. We know that animals lived, and still live, having none of these; and, as we learn more and more about the lowly ancestors of the higher animals, so we discover how such structures were acquired. Of the numerous variations which occurred in the offspring of animals, some perished with the young themselves; but other variations, especially those benefiting the holders in the struggle for life, were handed down to subsequent generations, and so in time became greatly developed and fixed, till, in the course of ages, two distinct sets of animals, originating in the same group, but taking advantage of different variations, became as specialized and unlike each other as pianos and rifles.

To appreciate the relationship that extends through the whole animal kingdom we ought to begin by a study of our own family and relatives. A child may have one striking feature of its father, another of its mother, or blend both so that it shows but little resemblance to either parent—in fact, it presents a new variation. Or there may be some oddity of appearance or manner strikingly like the child's grandparent,

FIG. 146 (Left).—A Group of Domestic Pigeons.

All these diversified forms have been evolved by man, in a comparatively few years, from a wild ancestor resembling the modern blue rock, by means of artificial or conscious selection.

or even the grandparent's grandfather. Such features often run through many generations.

One species shades almost imperceptibly into another; one genus, separated from another by thousands of years, is found to have come into being by countless changes—branchings in the tree of life, we might call them. There can be but one explanation of this marvellous network of living and once-living things—to wit, that they are all of one family by descent, and that all the striking changes they present have come about through gradual modifications. It is this "descent by modification" that constitutes "evolution." Scarcely any well-informed person to-day denies the *fact* of Evolution, though he may not admit this or that *method.* Underlying the incontrovertible fact of Evolution, and explanatory of its *modus operandi*, are certain principles, some of which are so invariably and essentially present as to be called *laws.* These principles include: Heredity, Variation, Over-production, Struggle for Existence, Natural Selection, Survival of the Fittest, Elimination of the Unfittest, Over-population, Segregation, Sexual Selection, Artificial Selection, Environmental Pressure, Competition, Atrophy and Hypertrophy, Momentum, Convergence, Mimicry, etc. We will just touch upon some of the more important of them.

(1) *The Law of Heredity.*—Like produces like. Sheep produce sheep; cats, cats; children resemble their parents. This, the law of heredity, has been recognized and acted upon for thousands of years by everyone.

(2) *The Law of Variation.*—The children of the same family are not all *exactly alike*; neither are they exactly like their parents. In short, they *vary.*

This is because the outside forces, which we name "environment," are never exactly the same in their action upon different individuals. There are various factors, internal and external, which produce the variations which make evolution possible. If the offspring were always exactly like their parents, there could be no advance—no improvement. This Law of Variation has also been known and recognized for thousands of years. If any farmer were to kill all his stock which were not exactly like their parents, he would have no stock. The causes of variation are obscure, but all are probably traceable to the action of the environment upon the germ cells of either or both of the parents. Variation is well shown in pigeons. Zoologists are now agreed that all domestic pigeons have been derived from the wild blue rock. Fig. 146 shows a group of pigeons many of which are utterly unlike their wild ancestor.

Look at the pouter, which seems to have swallowed a football, and the

fantail, which seems to be trying to bury its head in a fire-screen. By such examples of variations from the same relatively recent ancestors we see that species change and that new ones arise. These changes in pigeons have been brought about chiefly by man's agency; and his acts of choice are called *conscious* (or *artificial*) *selection*, for it is man who has selected the points or variations which he wished to develop.

Man selects the points which are to *his own* advantage; "Nature" (if we may be pardoned for personifying these blind evolutionary processes) selects the points which are directly to the advantage of the living creature itself, and indirectly to that of the species to which it belongs.

(3) *The Law of Over-production and Over-population*; that is, that more of all kinds of living things come into being than can remain alive.

So manifest is this law that it needs little explanation. As Darwin says: "There is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair." Man has been known to double his number in twenty-five years; and, at this rate, in less than a thousand years there would literally not be standing-room for his offspring. What shall we say, then, of such animals as the cod-fish, oyster, and tape-worm, that produce, respectively, a million, two million, and over a thousand million offspring annually? Under no imaginable conditions could all these creatures live and go on reproducing at such a rate in a small world like ours.

(4) *In consequence of more beings coming into existence than can live, there is a Struggle for Existence.*

All organisms naturally try to live, but as there is not sufficient accommodation and food for

FIG. 147.—Two Pigs.
(After *Romanes*.)

The pig above is evolved by Nature; the other, by man's artificial selection, for the sake of its "bacon"! What chance of survival would this domestic pig have in the environment of its wild ancestors?

the vast numbers produced, and as most organisms live upon, or at the expense of, others, it follows that the destruction is on an inconceivably vast scale. In six square feet of ground Darwin found that out of 357 weeds that came up, 295 were destroyed, chiefly by slugs and insects. Not only among lower animals and plants, but among savage and civilized races of men, a similar and no less fierce struggle for existence is ever waging.

(5) *In the Struggle for Existence the fittest survive.*

By " fittest " we do not mean the best according to any *ideal* standard, but those most suited to cope with the particular existing circumstances. If you have 1,000 people at a railway station who have been to a football match, and the train can take only 600, clearly 400 will have to stay behind. Do you think the football team would be among the 400 left behind? The players may not be very scientific, philosophical, or poetic men, but they have certain qualities which are of great service to people who wish to get into trains; so they are not left behind. Such is the *success of the fittest*!

Again, by Natural Selection we do not mean conscious selection, or design, or conscious working for an end. Darwin's term, " Natural Selection," means that, in a world of struggling beings, natural processes will destroy some and leave others, so that the weak and ill-adapted are weeded out. To give a homely example: one might succeed in rearing chickens and ducks in a small yard in ordinary weather. But if a sudden deluge of rain filled the yard to the depth of two or three feet, the chickens would drown, while the ducks would swim about happily. The ducks would be the fittest to survive a deluge of rain. On the other hand, if these creatures were being reared in a field with very little shelter, the chickens would take to roosting in the hedges or trees, but the ducks would have to remain on the ground, where they would fall an easy prey to foxes. Chickens are obviously the fittest to survive in this case. These

FIG. 148 (Right).—A Group of Dogs.

All these domestic dogs have been evolved through man's artificial or conscious selection. Despite their very different appearances, they are, like the Colonel's lady and Mrs. O'Grady, the same under the skin. Their skeletons are built up of the same bones. They carry in each jaw the same teeth: three incisors, one large canine, four premolars, two molars in the upper jaw, but three in the lower; or, to use the zoologist's formula $\frac{3.1.4.2}{3.1.4.3}$. Dogs are digitigrade animals, walking on their toes, of which there are five in the fore feet, four in the hind feet; though the dew-claw, a rudimentary great toe, represents a fifth toe. Dogs belong to the sub-order Fissipedia and the Section Cynoidea, which includes the timber wolf, *Canis lupus*, the coyote, *C. latrans*, the jackal, *C. aureus*, and the fox (red), *Vulpes Vulgaris*. Dogs cannot retract their claws as can the Cats (lion, tiger, civet, hyæna). Dogs number 104 living species, and 160 extinct. They first appeared in the upper Eocene of Europe.


1. Chow Chow. 2. Sussex Spaniel. 3. Dachshund. 4. Pekinese. 5. Saluki. 6. Fox Terrier (Wire). 7. Bulldog. 8. Cairn Terrier. 9. Irish Setter. 10. Fox Hound.

illustrations are the more interesting because chickens and ducks are nearly related. They come from a common ancestor not very far back—an ancestor that was neither fowl nor duck, yet possessed some points of both.

Now, changes of circumstances such as those just outlined have been constantly taking place for millions of years, and it is quite clear that creatures entirely unfitted for the new circumstances perished. A very small thing might easily determine whether a savage or a poet should live or be destroyed.

Natural Selection is infinitely more powerful, efficacious, wide-reaching, and more lasting in its effects, than are the puny efforts of our artificial selections. It works solely upon the single principle—the advantage to the individual. In it is no pity, no mercy, no dream of the good of the whole. Ever it backs up its favourites—those who possess the requisite capacities to live successfully—cherishing them, fostering and furthering their pursuits. With deadly accuracy it eliminates the failures so to live—their mute appeal is invariably met with down-turned thumbs. It sees to it that individuals with favourable variations transmit these to offspring, and thus subsequent generations tend to get better and better adapted to their surroundings.

Those who still argue that we cannot see Evolution at work should consider the marvellous products—flowers, fruits, and domestic animals—that are a familiar feature of modern civilization, many of them quite unknown in the days of Queen Elizabeth.

The animals in Fig. 147 are both pigs. Man, in a comparatively few years, has evolved the white domesticated pig from the very unlike black wild hog.

No one supposes that each kind of dog in the group shown in Fig. 148 was separately and specially created. These very dissimilar animals, if found wild, would be classified as different species; yet they belong to one family, the *Canidæ*, which includes foxes, wolves, jackals, and dogs—all

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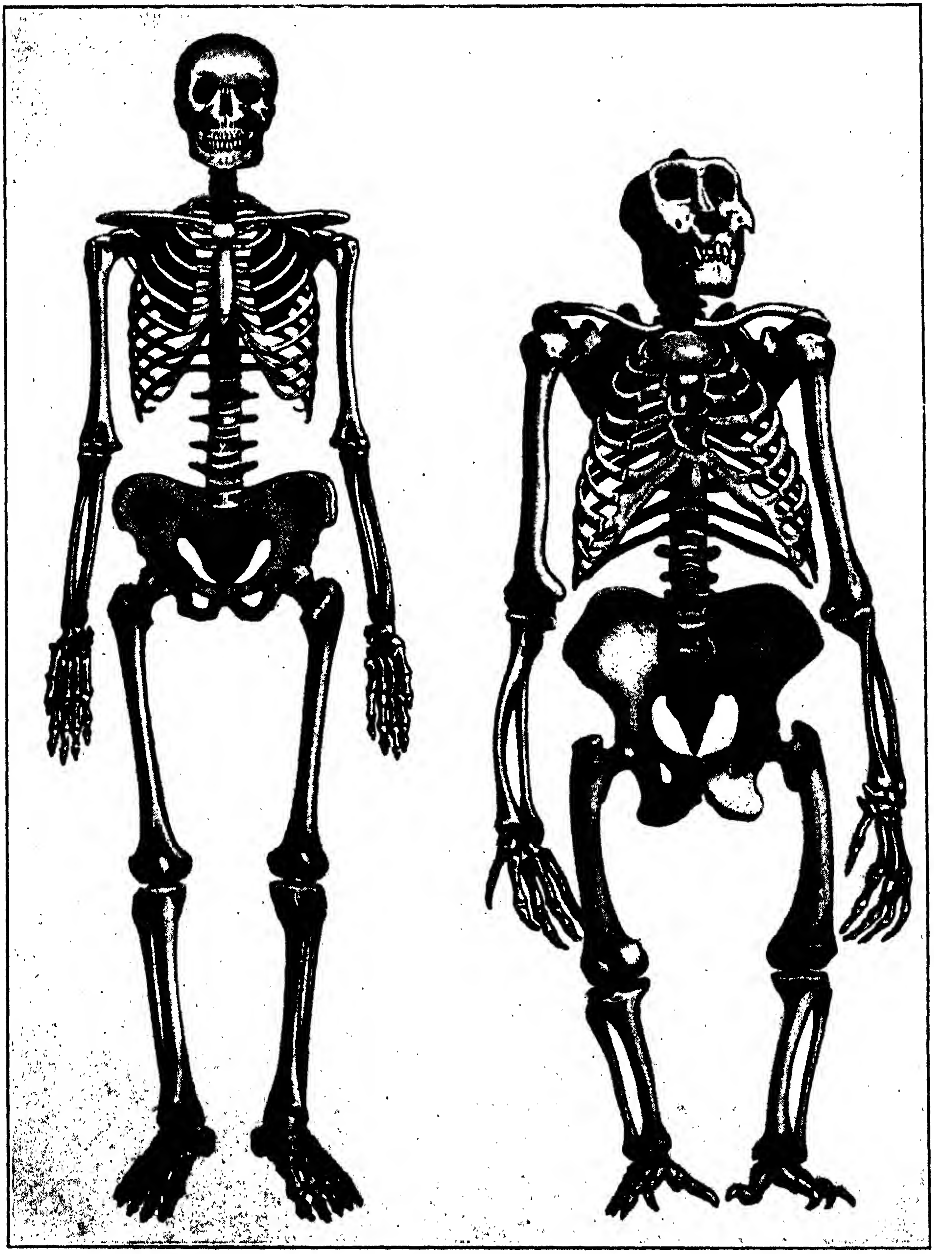
Fig. 149 (Right).—Skeletons of Man and Gorilla.

Man and gorilla belong to the Order *Primates*, sub-order *Anthropoidea*. Both are tailed as embryos; tailless after birth. Neither has an *Os centrale* in the wrist. Man differs from the gorilla in his domed high skull (which lacks the gorilla's powerful bony crest), his very decided chin, and his large brain—48½ oz. to the gorilla's 19 oz. Man has an easy erect posture, standing, walking, or running—a great help in his cultural progress, since it frees his hands for the examination of objects and for other purposes. The gorilla has a shuffling bipedal gait, and its erect posture, even for standing, is maintained with difficulty. Man, too, has articulate speech, but has lost the hairy coat of the gorilla. Both man and gorilla are museums of relics; 180 vestigial structures are to be counted in man alone. Man arose, not from any living type of Great Ape, but from an ancestral stock common to both, probably about 8 to 10 million years ago, in the mid Pliocene. This was when Pithecanthropus flourished. The first definite human fossils are Pleistocene.



Skeletons of Man and Gorilla.

descendants of some common *Thooid* or wolf-like ancestor resembling, if not identifiable with, the Eocene *Cynodictis*.

Again, in the case of domestic fowls we see how new and distinct varieties are formed by fanciers selecting the variations they desire. The old notion that species are fixed is, then, not true, for they can be modified in many ways. The various kinds of animals have evolved to their present state in consequence of the repeated selection of certain of these modifications.

The many points of likeness between man and some lower animal constitute striking evidence of that common descent which Evolution teaches. Both require food, digest it, and throw out waste products. Both die if cut off from air. Both must have rest and sleep, both grow from infancy to maturity, reproduce their kind, suffer the decay of old age, and finally die. So akin are man and the higher mammals that they are subject to many of the same diseases—pneumonia, tuberculosis, anthrax, glanders, hydrophobia, rheumatism, and even measles! The higher we go in the animal scale, the more striking and detailed do such resemblances become.

The skeletons of man and ape shown in Fig. 149 exhibit a remarkable similarity in general plan. If you fix your attention on any bone or arrangement of bones you will find it paralleled in the other skeleton.

So, too, if with the skeleton of man you compare that of a fish, frog, lizard, rabbit, and lemur, you will find that, while all present resemblances, these become more and more marked as we pass up the series in the order mentioned.

# CHAPTER SEVEN: DEVELOPMENT AND VARIATION

MOST minds are hostile to new ideas because the human brain is a relatively recent and imperfectly developed instrument. Since all intelligence results from the action of outside forces upon the nervous system, it is manifest that, following the impact of a new set of forces upon the brain, there is liable to ensue something of the nature of a shock. This explains why one's mental *attitude* so largely determines the power to receive fresh ideas. All people are capable of understanding "Evolution," but many approach the subject with a fixed desire to destroy rather than to comprehend it.

Those who have been taught incorrect surmises about the beginnings of the earth and of man are handicapped at the start by enemies, in the shape of preconceived ideas, which contest every approach of truth and constitute a far more formidable barrier than mere ignorance. So long, however, as false explanations of the world are deemed good enough for children, such enemies will drag the human race in captive chains.

"Early ideas are not usually true ideas. Undeveloped intellect, be it that of an individual or that of the race, forms conclusions which require to be revised and re-revised before they reach a tolerable correspondence with realities. Were it otherwise, there would be no discovery, no increase of intelligence. What we call the progress of knowledge is the bringing of thoughts into harmony with things; and it implies that the first thoughts are either wholly out of harmony with things or in very incomplete harmony with them. If illustrations be needed, the history of every science furnishes them. The primitive notions of mankind as to the structure of the heavens were wrong; and the notions which replaced them were successively less wrong. The original belief respecting the form of the earth was wrong, and this wrong belief survived through the first civilizations." (Herbert Spencer.)

Many people are still satisfied with the "early ideas" of man when he was but little better than a savage, and speak of comets, witches, and ghosts in the ignorant manner of the lowest races. Such people are thousands of years behind modern science, and to them half the world has no meaning. One of these "early ideas" is that each species was separately created and has remained the same ever since. The life of man is so short that only in such instances as certain bacteria, the shelled

amœba *Difflugia Corona*, the fruit-fly *Drosophila*, and the Porto-Santo rabbit, has the production of new types been actually observed. Man is apt to flatter himself as being the latest product of Evolution, but the human louse—which is dependent upon man—is a much later product. Yet more significant is the fact that the lice of man have their nearest relatives, not in those of birds or dogs, *but in the lice of monkeys and apes*! The same species of louse is found upon closely related species of animals, even though these may be widely separated, as in the case of the North American and Egyptian kingfishers, or the North American and Siberian ground squirrels.

FIG. 150 (Left).—*Chrysanthemum Indicum.*
The ancestor of the modern Chrysanthemum.

The essential organs of a flower are the stamens and carpels; the non-essential ones the petals and sepals. Most botanists believe that petals and sepals evolved by modification of sporophylls, or spore-bearing leaves.

FIG. 151.—Chrysanthemum.

There are two wild chrysanthemums in Britain, popularly known as the Yellow Ox-eye, or Corn Marigold, and the White Ox-eye.

Here it will be well to explain that what is meant by this very arbitrary word *species* is a group of living individuals resembling each other closely, the several members of which can interbreed and produce potentially fertile offspring. Some of the extremes of our domestic dogs, for instance mastiff and toy-terrier, could not, for physical reasons, breed together; others, if interbred, would beget infertile offspring just as the horse and ass beget the infertile mule. So we should be quite justified in regarding the mastiff and toy-terrier as belonging to the same genus but to different species; indeed, they are new species evolved through man's agency. The animals and plants of our farms and gardens are proof of the many existent *varieties* which, in a few years, man has brought into being, and these are the actual stepping-stones to *new species*. We must remember, however, that the grouping of animals and plants in species is no *natural* division, but a labour-saving device to help in classification. Two methods are used by biologists in this process; the living things may be grouped together in accordance with their actual relationship, or from the standpoint of their life-conditions; the former method is termed *Taxonomy*, the latter, *Bionomics*. An example of the complete classification of some animal, say, a tiger, may be of use to the student.

*Individual.* A tiger at the Zoo.
*Variety.* The cave tiger or the jungle tiger.
*Species.* *Felis tigris*, or *Felis domestica.*
*Genus.* *Felis.*
*Family.* *Felidæ*—cat, lion, leopard, jaguar, cheetah, ounce, ocelot, and lynx.
*Order.* *Carnivora* (flesh-eaters).
*Class.* *Mammalia* (suckle their young).
*Section.* *Craniata* (possess a definite head).
*Sub-phylum.* *Vertebrata* (possess a backbone).
*Phylum.* *Chordata* (possess a notochord).
*Sub-kingdom.* *Metazoa* (multicellular).
*Kingdom.* *Animalia* (an animal).
*World.* *Organic* (it is alive).

Few people would be able to recognize in Fig. 150 (*Chrysanthemum Indicum*) the ancestor of our modern Chrysanthemum (Fig. 151). The latter shows what man can do by selecting and propagating variations which are favourable to his purpose, though by no means to the plant's welfare from Nature's view-point. The half-lop rabbit shown in Fig. 152 exemplifies what Artificial Selection can effect in the animal world.

FIG. 152.—Half-lop Rabbit.

This long-eared rabbit is a descendant, by means of Artificial Selection, of the common wild rabbit. The original home of the latter was the Western Mediterranean, whence it spread all over Europe and Britain. Introduced to Australia and New Zealand, it flourished, multiplied and spread so rapidly that it has become a pest. Yet the long-eared rabbit, owing to the handicapping to which it would be subjected by its ears, if returned to Nature, would not survive more than a few days.

In Fig. 153 you see a pony with zebra-like stripes on its shoulders and forelegs. Such stripes—the marks of wild ancestors—will sometimes appear in horses and donkeys, though neither parents nor grandparents had them. This form of variation is called an " atavism " (Lat. *atavus*, forefather) or " reversion "—in breeders' parlance, a " throw-back." All kinds of animals are liable to show this remarkable trait. A lizard that has lost its tail sometimes grows a new one bearing scales like those of an ancestral species. The primitive blue-rock colour sometimes turns up unexpectedly in an apparently pure fancy breed of pigeon. Children born of sickly parents often exhibit ape-like features, and certain parts of the brain of some insane people and criminals are undoubtedly reversions. Dapples on horses, as previously stated, are probably relics of ancestral skin-plates. *All* mammals have come from a group of scaly reptiles. The armadillo (Fig. 154) is a mammal in which hairs can be seen growing between the scale-like plates. In some mammalian ancestors the hair used to grow round each scale; in others between the

FIG. 153.—Devonshire Pony, showing ancestral Stripes; a typical instance of atavism.

rows of scales. The hair in the modern descendants of the former shows a dappling arrangement (Dasypus, an armadillo); of the latter, a striped arrangement (Myrmecobius) (Fig. 155). The scaly pangolin (Fig. 156) has hairs between the plates when it is young, but in the adult the hair is glued together to form overlapping scales. It is a true tree-climbing ant-eater, belonging to the primitive order *Edentata* (toothless).

That strange group, the modified mammals (Metatheria), to which the banded ant-eater (Fig. 155) just alluded to belongs, includes the curious pouched mammals of Australia and neighbouring islands, as well as the opossums of America.

## Kinds of Development

Every individual, in its growth from a fertilized egg to an adult, repeats to a great extent those several stages through which its ancestral line has passed. This process is called "the fundamental law of biogeny," or the "biogenetic law," and it may be summarized in Haeckel's words thus: "*Ontogeny is a brief and condensed recapitulation of Phylogeny.*" Were each human being in its ontogeny to repeat, even perfunctorily, every stage of its million centuries' phylogeny, it would require more like nine years' than nine months' gestation. But the human embryo, in common with every other embryo, has learnt, by various adaptations (*cenogenesis*),

Fig. 154.—Armadillo.

A modern representative of the extinct Oligocene–Pleistocene Glyptodonts. The living armadillo, like its extinct forebears, lives in South America. It is a nocturnal, omnivorous animal capable of rapidly digging itself into the ground. Note the hairs that still persist in growing between the bony scutes of its dermal armature.

FIG. 155.—Banded Ant-eaters (*Myrmecobius fasciatus*).

It is an insectivorous marsupial of Australia and is noteworthy as possessing more teeth than any other marsupial. It has a long protrusible tongue specially evolved for feeding on ants. Curiously enough the Myrmecophagidæ, a closely-allied family of ant-eaters, which also possess long thread-like protrusible tongues, have not even traces of teeth.

to get quickly to its full development; it has made short cuts, so to speak, in its *palingenesis*.

In fine, certain of the stages of growth manifested by the embryo (especially that of the later and higher animals) are not recapitulations of a remote past, but are definite modern adaptations to the altered conditions of a fast-changing environment.

Here it will be well to explain certain words just used:—

*Biogenesis* (*bios*, life; *genesis*, origin). The origin and development of living things.

*Cenogenesis* (*kainos*, new). The introduction of new features or structures whereby the embryo can hasten on its ontogenesis.

*Ontogenesis* (*on*, organism). The development of the individual organism —its embryology and growth.

*Palingenesis* (*palin*, again). The recapitulated racial history by the individual organism, especially during its pre-natal development.

*Phylogenesis* (*phylon*, race). The development or life-history of the race; that is, the ancestral history of an organism. Just as Embryology is the science of Ontogeny, so Palæontology is the science of Phylogeny.

In Fig. 157 the top row shows the palingenesis of an Ascidian, and

the bottom row that of Amphioxus. It will be seen that the recapitulations of the ancestral histories are practically alike. All animals above Ascidians pass through similar stages.

In order to understand more clearly what is meant by phylogeny and ontogeny, we may study Figs. 158 and 159.

In Fig. 158 we see the fossil antlers of deer; they well represent the phylogenetical development of these structures.

Fig. 159 depicts the ontogenetical development of the antler of *one* deer as it grows, year by year, till from a short spike, or tine, it becomes the highly-branched antler. The large group of animals that includes sheep, deer, camels, oxen, etc., is called "Ruminants." The first ruminants were hornless. In the early Miocene period deer had no antlers, but by the mid-Miocene they possessed two-pronged ones; and the higher we ascend in the subsequent beds of rock, the more prongs are found, till in the Norfolk beds of the Pliocene are found the many-pronged antlers.

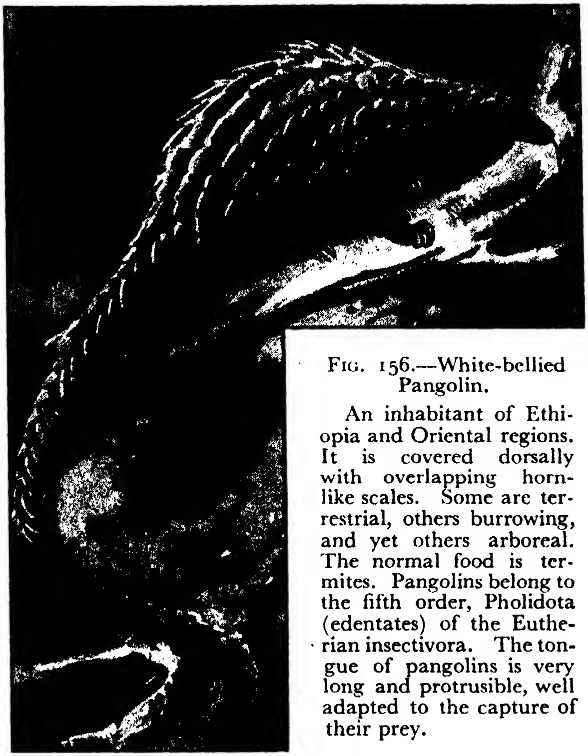


FIG. 156.—White-bellied Pangolin.

An inhabitant of Ethiopia and Oriental regions. It is covered dorsally with overlapping horn-like scales. Some are terrestrial, others burrowing, and yet others arboreal. The normal food is termites. Pangolins belong to the fifth order, Pholidota (edentates) of the Eutherian insectivora. The tongue of pangolins is very long and protrusible, well adapted to the capture of their prey.

Turning again to Fig. 159, we see the antler as it grows in any single stag. The one-tine form has not as yet been found among fossils; but in all the rest we see that the history of the individual is a repetition of that of the race—ontogeny recapitulates phylogeny.

A still more striking case of this law is found in the history of fish-tails.

"Among fishes," says Professor Le Conte, "there are two styles of tail-fins. These are the even-lobed, or homocercal (Fig. 160), and the uneven-lobed, or heterocercal (Fig. 161). The one is characteristic of ordinary fishes, such as the carp (teleosts), the other of sharks and some other orders. In structure the difference is even more fundamental

than in form. In the former style the backbone stops abruptly in a series of short, enlarged joints, and thence sends off rays to form the tail-fin (Fig. 162); in the latter the backbone runs through the fin to its very point, growing slenderer by degrees, and giving off rays above and below from each joint, but the rays on the lower side are much longer (Fig. 163). This type of fin is, therefore, *vertebrated*, the other *non-vertebrated*. . . . But there is still another type, found only in the lowest and most generalized forms of fishes. In these the tail-fin is vertebrated and yet symmetrical. This type is shown in Fig. 162.

" Now, in the development of a teleost fish (Fig. 160) . . . the tail-fin is first like Fig. 162; then becomes heterocercal, like Fig. 161; and finally becomes homocercal, like Fig. 160. Why so? Not because there is any special advantage in this succession of forms; for the changes take place either in the egg or else in very early embryonic states. The answer is found in the fact that *this is the order of change in the phylogenetic series*. . . . The earliest fish-tails were almost certainly like Fig. 162; then they became like Fig. 161; and, finally, only much later in geological history (Jurassic or Cretaceous), they became like Fig. 160. This order of change is still retained in the embryonic development of the last

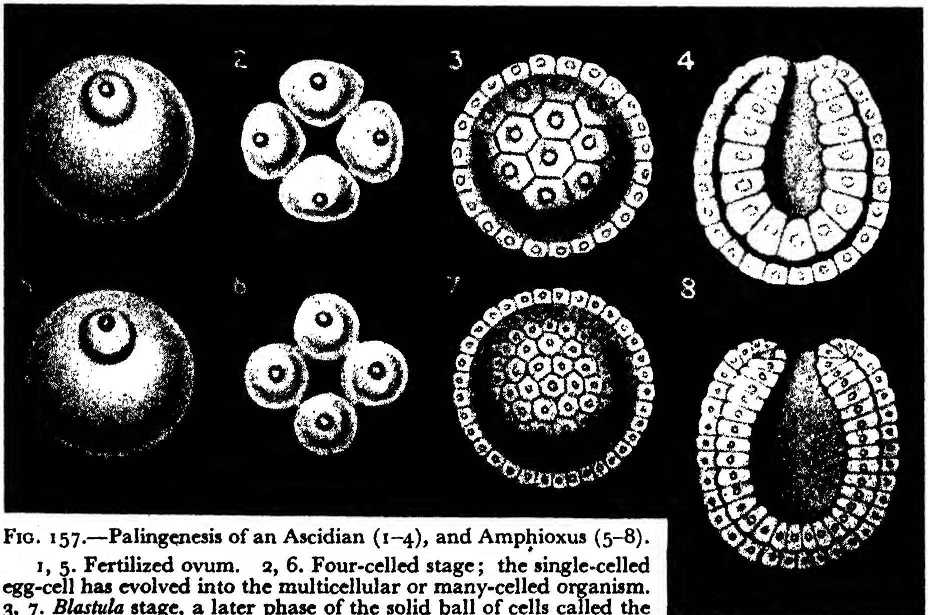



FIG. 157.—Palingenesis of an Ascidian (1–4), and Amphioxus (5–8).
1, 5. Fertilized ovum. 2, 6. Four-celled stage; the single-celled egg-cell has evolved into the multicellular or many-celled organism. 3, 7. *Blastula* stage, a later phase of the solid ball of cells called the *morula* stage. 4, 8. Section of *Gastrula* stage. The oval-shaped cavity is the primitive intestine, or *archenteron*, and the opening the primitive mouth.

introduced and most specialized order of existing fishes. The family history (phylogeny) is repeated in the individual history (ontogeny).

" Similar changes have taken place in the form and structure of birds' tails. The earliest known bird—the Jurassic Archæopteryx—had a long reptilian tail of twenty-one joints, each joint bearing a feather on each side, right and left (Fig. 163). (See also Fig. 112.)

" In the typical modern bird, on the contrary, the tail-joints are diminished in number, shortened up, and enlarged, and give out long feathers, fan-like, to form the so-called tail (Fig. 163). The Archæopteryx tail is *vertebrated*, the typical bird's tail is *non-vertebrated*. This shortening up did not take place at once, but gradually. The Cretaceous birds, intermediate in time, had tails intermediate in structure. The Hesperornis (Fig. 70, p. 72) had twelve joints. At first—in Jurassic strata—the tail is fully a half of the whole vertebral column. It then gradually shortens up until it becomes the aborted organ of typical modern birds. Now, in embryonic development the tail of the modern typical bird *passes through all these stages*. At first the tail is nearly one-half the whole vertebral column; then, as development goes on, while the rest of the body grows, the growth of the tail stops, and thus finally becomes the aborted organ we now find. The ontogeny still passes through the stages of the phylogeny. The same is true of all tailless animals."

## DIFFICULTIES

Ever since 1859, when Darwin convinced thoughtful men and women that the master-key to all cosmic problems was Evolution, biologists have

FIG. 158.—FOSSIL ANTLERS.

Their phylogenesis, or ancestral history, is shown. Towards the left are shown the antlers of early types of deer; towards the right the antlers of later types.

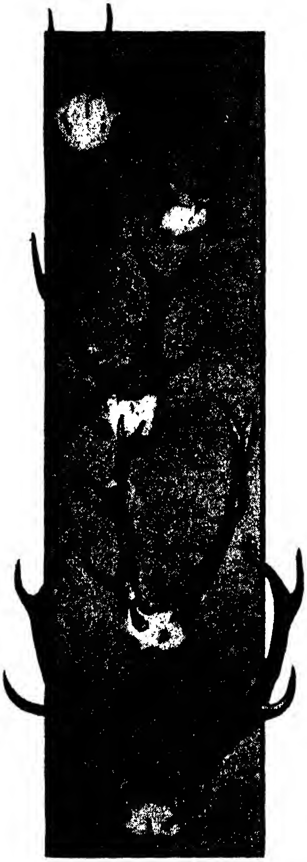


FIG. 159.—Antlers of one Deer.

Here the ontogenesis, or individual evolution, of the antler of a deer is shown; above, the unbranched antler is that of a very young deer; below is the many-branched antler of the same deer when mature and full-grown.

been emphasizing the facts that it does not proceed in a straight line to something "better" in every single instance; that man has not come from any existing order of ape; that survival of the fittest does not mean survival of the loveliest, noblest, or tenderest; that Natural Selection is neither the *sole* nor even the necessary moulder of the world, nor is it a teleological—that is, a conscious and purposive—selection; that relatively persistent species are not absolutely *immutable* species.

All these cautions against error have been available to the reading public for over half a century; yet if one meets with an objection to Evolution it is almost certain to be one of these. Anti-Evolutionists are apt to talk glibly of missing links without the least idea as to what it is they mean by the expression; they argue that because man has no tail he cannot be related to the apes, overlooking the obvious fact that, if he were tailed, his condition would constitute a very powerful argument against close relationship to the apes, for they are tailless!

## TIME

The vast period of time required to meet the demands of the biologist used to be, but is no longer, a difficulty. There are, however, other points with regard to time that are of intense interest to us: such as the time when man first appeared on the earth, the time when the latter cast off the moon and was itself cast off from the sun. None of these dates is *absolutely* settled, but astronomers can give us a very fair idea of the *relative* periods involved.

The question of the time-duration of life is one that has been carefully studied along two different lines, biological and physico-chemical. In the last few years physicists and chemists, supported by overwhelming

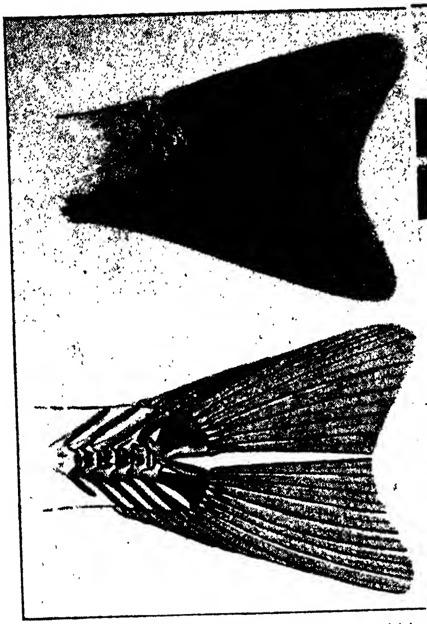


FIG. 160.—Homocercal Tail, showing (A) external form and (B) internal structure.

Note that the vertebræ of the backbone do not enter the tail.

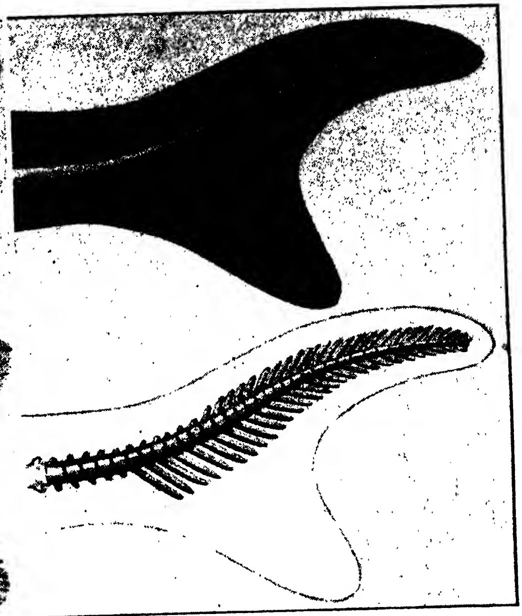


FIG. 161.—Heterocercal Tail: (A) external form, (B) internal structure.

Here the vertebræ of the backbone pass to the tip of the upper lobe of the tail-fin.

evidence from the radio-active elements, have enormously extended the earth's life-bearing period. Whereas, forty or fifty years ago, fifty million years was considered a somewhat audacious demand for this, scientists now tell us that the age of the earth is between 1,600 million and 3,000 million years, and that probably some 1,260 million years have elapsed since lower pre-Cambrian times. By taking a mean of numbers given by various scientists we may safely assume that life of some sort has existed on this planet for 1,250 million years. It is difficult to form any conception of so vast

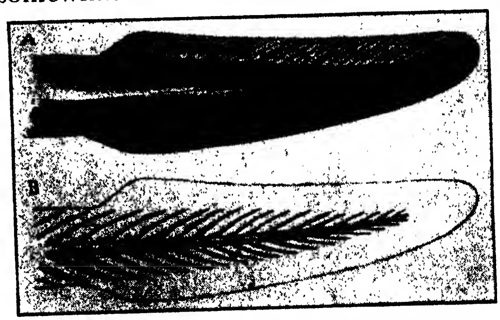



FIG. 162.—Vertebrated yet symmetrical Fin: (A) external form, (B) internal structure.

The vertebræ of the backbone pass down the centre of the tail fin to a point near its end.

a period as this, but the following scheme may help. Following Haeckel, let us call the whole life-history of the earth one cosmic day, and make 12 hours correspond to 1,250 million years, one hour to approximately 104 million years, a minute to about one and three-quarter million years, and one second to approximately 28,000 years. If, now, we reduce the geological formations to this one-round-of-the-clock scale, we obtain some very impressive results. Life started at midnight, while 12 o'clock noon represents present time. The first point to be noticed is that the very simple types of living things which dwelt in the pre-Cambrian seas of the Archæozoic and Proterozoic ages occupy over one half of the total life-bearing history. Chordate animals only begin to appear about 7.30 a.m.

Lung fishes come on the scene about 8.40 a.m. About 9 a.m. the Amphibians appear and the first known land-flowers begin to brighten the earth. Some twenty-five minutes later, reptiles are crawling about. At 10.10 a.m. reptile-mammals come on the stage, followed, at about 10.30 a.m., by the reptile-birds. At 10.50 a.m. the Lords of Creation are the giant saurians, but they have gone the way of all flesh by 11.10 a.m.! Five minutes later, egg-laying mammals are well to the fore, followed in a few minutes by the placental mammals. By 11.24 a.m. miniature elephants and horses are in being; but not until 11.30 a.m. does the lowest Primate (lemur) show itself—to be accompanied, in another five minutes, by the first monkeys. At 11.38 a.m. apes appear; and by 11.50 a.m. ancestors of our gorilla, chimpanzee, orang-utan, and gibbon are climbing about the Miocene forests. At 11.52 a.m. we catch a fleeting glimpse of the first known humanoid, *Pithecanthropus erectus*, slouching about the Siwalik valleys of Java. About four minutes later we are witnessing the transformation of the more ape-like creatures into the more

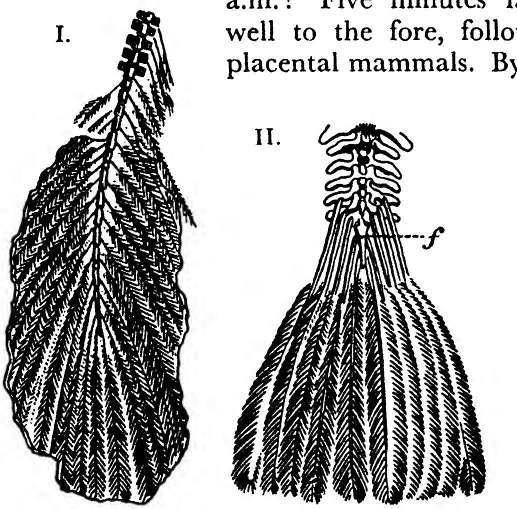
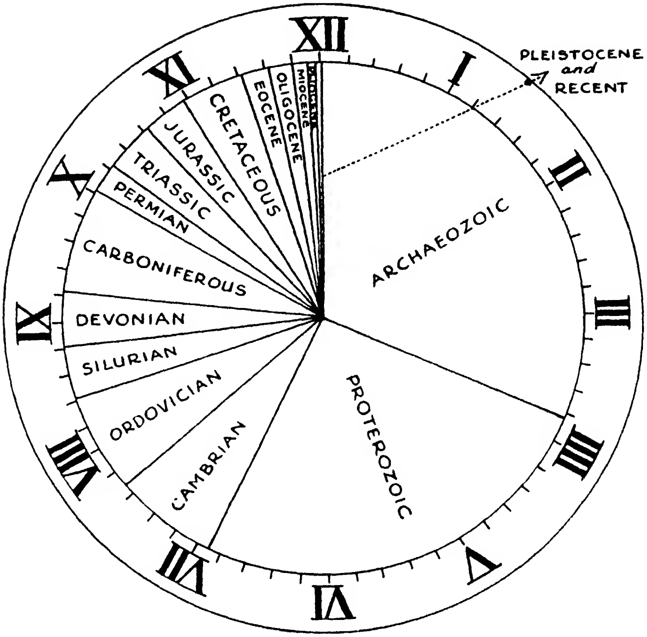



FIG. 163.—I. Tail of the primitive bird Archæopteryx. It is composed of 21 *free* caudal vertebræ, of which the 9th to the 20th each supports a pair of feathers. II. Tail of a modern bird. It is made up of about 18 caudal vertebræ, of which 6 are fused with the sacrum, 6 are free, and 6 go to the formation of a triangular-shaped bony mass known as the *pygostyle* (*f*) which carries the tail-feathers.

man-like ones. At 11.57 a.m. tool-using man is on the scene. At a minute to midday the prevailing glacial conditions are causing an almost wholesale extinction of the great mammals. Just about one second before the clock strikes 12 noon, historic man appears! In this last second are crammed all the marvellous discoveries and feats of *Homo sapiens*—from




| Period. | Duration in years. | No. of years ago to commencement of period. | Duration on 12-hour clock scale. | | | Time on clock when period began. | | |
|---|---|---|---|---|---|---|---|---|
| | | | H. | M. | Sec. | H. | M. | Sec. |
| Present Day | — | — | | — | | 12 | 0 | 0 |
| Recent | 20,000 | 20,000 | 0 | 0 | 0·7 | 11 | 59 | 58 |
| Pleistocene | 980,000 | 1,000,000 | 0 | 0 | 34 | 11 | 59 | 25 |
| Pliocene | 7,000,000 | 8,000,000 | 0 | 4 | 2 | 11 | 55 | 23 |
| Miocene | 12,000,000 | 20,000,000 | 0 | 6 | 54 | 11 | 48 | 28 |
| Oligocene | 15,000,000 | 35,000,000 | 0 | 8 | 38 | 11 | 39 | 50 |
| Eocene | 25,000,000 | 60,000,000 | 0 | 14 | 24 | 11 | 25 | 26 |
| Cretaceous | 50,000,000 | 110,000,000 | 0 | 28 | 48 | 10 | 56 | 38 |
| Jurassic | 30,000,000 | 140,000,000 | 0 | 17 | 17 | 10 | 39 | 21 |
| Triassic | 40,000,000 | 180,000,000 | 0 | 23 | 2 | 10 | 16 | 18 |
| Permian | 25,000,000 | 205,000,000 | 0 | 14 | 24 | 10 | 1 | 54 |
| Carboniferous | 80,000,000 | 285,000,000 | 0 | 46 | 2 | 9 | 15 | 51 |
| Devonian | 45,000,000 | 330,000,000 | 0 | 26 | 0 | 8 | 49 | 56 |
| Silurian | 40,000,000 | 370,000,000 | 0 | 23 | 0 | 8 | 26 | 53 |
| Ordovician | 78,000,000 | 448,000,000 | 0 | 45 | 0 | 7 | 41 | 57 |
| Cambrian | 77,000,000 | 525,000,000 | 0 | 44 | 18 | 6 | 54 | 0 |
| Proterozoic | 325,000,000 | 850,000,000 | 3 | 7 | 12 | 3 | 50 | 24 |
| Archæozoic | 400,000,000 | 1,250,000,000 | 3 | 50 | 24 | 12 | 0 | 0 |
| Total | 1,250,000,000 | — | 12 | 0 | 0 | | — | |

the building of the Great Pyramid, by Cheops, to the formulation of such theories as those of Natural Selection by Darwin and Wallace, of Quanta by Planck, and Neo-Relativity by Einstein; and to such practical achievements as aeroplanes, wireless, gyroscopes, Fido, Pluto, Radar, and the harnessing of intra-atomic energy as exemplified in the "atomic bomb."

# CHAPTER EIGHT: COMPARATIVE ANATOMY

A FEW vain people are still hurt when they learn for the first time how closely their bodies resemble those of lower animals in consequence of descent from a common ancestor.

It is well known that man and the horse have both come from the same early group of animals. If we were to trace their ancestors far enough back we should see that they and all other mammals have come through the Theromorpha, or mammal-like reptiles. It is therefore interesting to take the skeleton of the horse and compare it, bone by bone, with that of man (Fig. 164). The first thing that strikes us is that both have almost exactly similar bones; their skeletons must, therefore, have been acquired *before* their ancestors parted to go on separate lines of evolution.

We should see the similarity of the skeletons even better had the man been shown resting on fingers and toes in the quadrupedal position. Some animals, such as man and the bear, have a *plantigrade* gait—that is, they walk on the flat of the foot; others, such as the horse, have a *digitigrade* gait—that is, they walk on the tips of their digits.

The horse belongs to the large group of hoofed animals, the Ungulates. This group is divided into the even-toed, or Artiodactyles, and the odd-toed, or Perissodactyles (Greek *artios*, even; *perissos*, uneven; *daktylos*, digit).

The artiodactyles (even-toed) include the pig, deer, ox, sheep, goat, camel, giraffe, hippopotamus. Their feet are formed on the plan of B, in Fig. 165.

The perissodactyles (odd-toed) include the horse, tapir, rhinoceros, elephant. Their feet are formed on the plan of A, in Fig. 165.

In Fig. 166, A shows the human foot; B and C show what would be the foot used by the dog and the horse if they walked as man does, instead of upon their toes. It is very interesting to compare these three feet and especially to note *b* in the horse; this is the ergot (Fr., spur), usually concealed in the hair; it is useless—a relic of a pressure pad corresponding to that in the dog's foot, marked *b*, and bears eloquent testimony to the unity of structure underlying all mammals, and their probable descent from some generalized type. Thus we see that the horse walks on one finger only, and that the hoof is simply the middle finger-nail (Fig. 167).

Fig. 168 teaches us how two skulls, though widely different in appear-

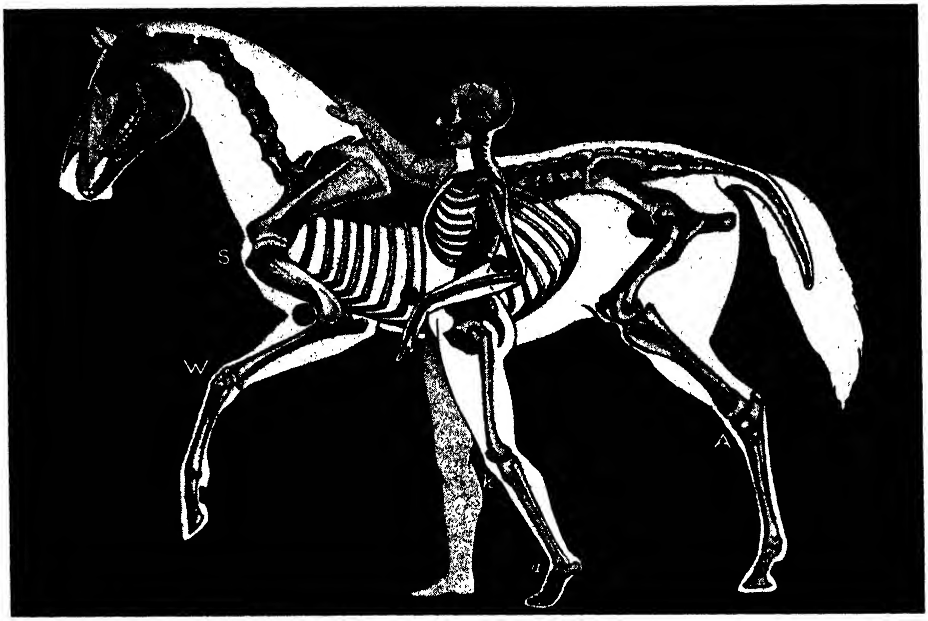



FIG. 164.—Comparative View of the Skeleton of Man and Horse.

S, shoulder joint; E, elbow joint; W, wrist joint (knee in horse); H, hip joint; K, knee joint (stifle); A, ankle joint (hock).

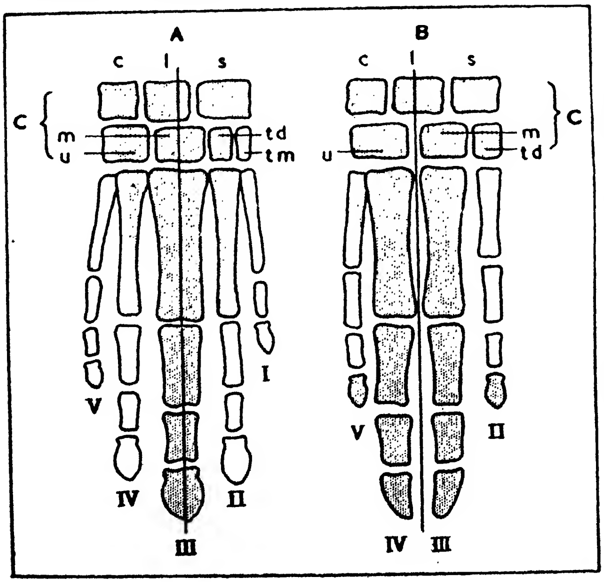



FIG. 165.—(A) *Perissodactyles*, or Odd-toed: Horse, Tapir, Rhinoceros, and Elephant. (B) *Artiodactyles*, or Even-toed: Pig, Deer, Ox, Camel, Giraffe, and Hippopotamus.

(A) is a diagrammatic representation of the right forefoot of an odd-toed animal; (B) of an even-toed. (C) the carpus, consisting of two rows of bones, the upper being *c*, cuneiform; *l*, lunar; and *s*, scaphoid: the lower, *u*, unciform; *m*, magnum; *td*, trapezoid; and *tm*, trapezium. The long bones in contact with the last constitute the metacarpus; the remaining ones are the phalanges. The digits, or toes, are numbered in order from the inner to the outer side of the foot. The shaded parts of (A) are those that are present in the horse; of (B) in the ox.

ance, yet contain all the essential parts in common. It shows that the great difference in the human skull is due to the large increase in brain development.

We must now compare man with some nearer relations—the Primates.

The numbers and letters in Fig. 169 correspond to the same parts. The group of small bones at the top of each forms the wrist, or carpus; the long bones, numbered 1, 2, 3, 4, 5, support the palm; after these come the three-jointed bones of the fingers, and the two-jointed ones of the thumb. To look at and count these bones is to be convinced that they are in origin identical. They furnish the strongest evidence that all the animals to which they belong should be placed in one group.

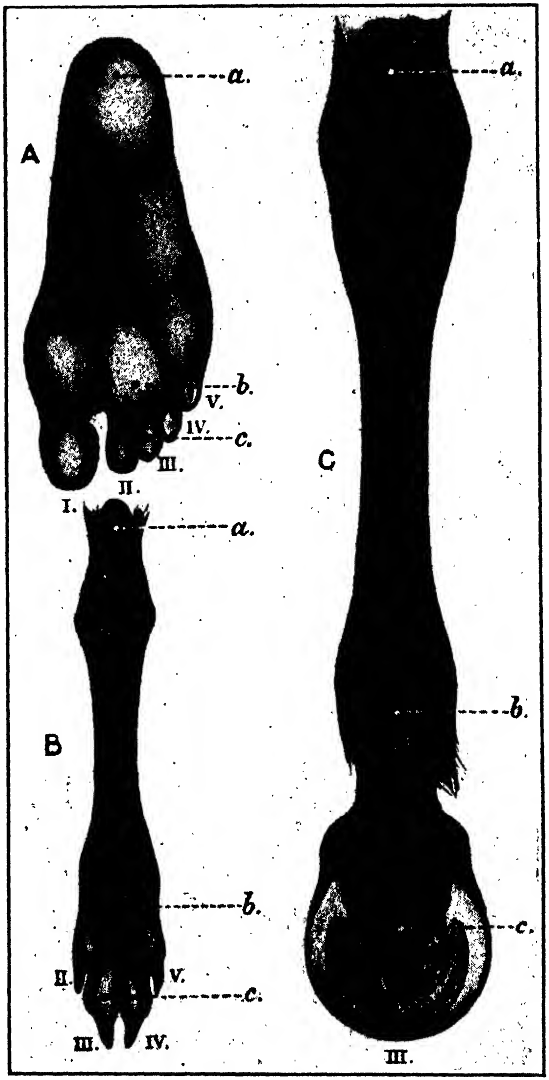



Fig. 166.—Plantar surface of the Foot of (A) Man, (B) Dog, (C) Horse. The letters *a*, *b*, and *c* indicate the corresponding points of the three. I, Big toe; II, Second toe; III, Third toe—that on which the horse walks; IV, Fourth toe—the dog walks on third and fourth toe; V, The fifth or little toe.

The most striking thing about the feet shown in Fig. 170 (here again the numbers and letters correspond to the same parts) is their great difference from the hands. The mass of bones at the top of each is the ankle-joint, or tarsus, and corresponds, in relationship, with the bones at the wrist-joint; but in the wrist there are eight bones, while in the ankle there are seven, for the large heel-bone, or *Calcaneus*, is really two bones that have

become "fused" together, and which correspond to the *Scaphoid* and *Lunate* bones in the wrist. Before the recognition of Evolution, men were classified as *Bimana* (two-handed), and the apes as *Quadrumana* (four-handed); but we now know that such differentiation was wrong, for both men and apes have two hands and two feet.

The most striking difference is seen in the big toe. In man it lies almost parallel with the other toes; but in the gorilla it is bowed out, so that it is opposable—*i.e.*, it can be pressed against the adjoining toe for grasping. (This arrangement is found in the human embryo, and may still be seen in a very young child after birth.) It was this use of the toe in grasping which gave to the apes the description *quadrumana*.

In the case of the fore limbs of these quadrupedal animals (Fig. 171) no one can doubt that they are all made on the same plan. Their differences are chiefly differences of arrangement, and, though in some cases bones have disappeared, in no instance do any *additional* bones appear.

As in the fore limbs, the similarity in the arrangement of the hind limbs (Fig. 172) is most striking. The dotted line 5 passes through the ankle-joint in each case. Man and ape are *plantigrade*, which means, as we saw above, that the whole foot is placed on the ground, while the dog, sheep and horse are *digitigrade*, that is, they walk on their fingers.

In the case of man, with the upright position given him by thousands of years of practice, the

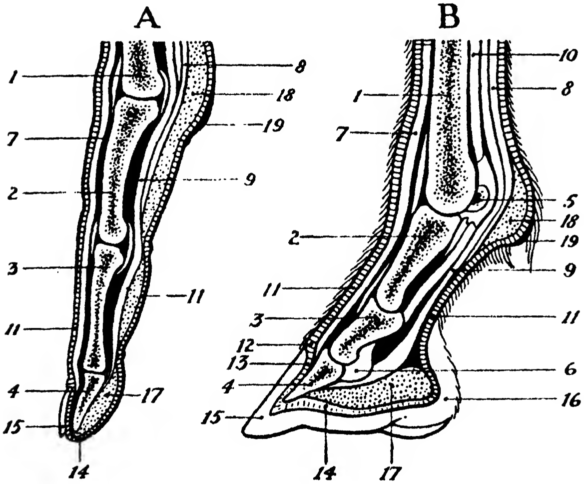



FIG. 167.—A, Section of the Finger of Man; B, Section of the Foot of Horse. In both A and B—1, metacarpal bone; 2, first phalanx; 3, second phalanx; 4, third or ungual phalanx. In A—7, tendon of extensor muscle; 8, tendon of superficial flexor; 9, tendon of deep flexor; 11 and 14, derm or true skin; 15, nail; 17, fibro-fatty cushion of end of finger; 18, ditto of palm behind meta-carpo-phalangeal joint; 19, thickened skin covering of same. In B—5, one of the upper sesamoid bones; 6, lower sesamoid; 7, 8, and 9, same as in A; 10, short flexor of fetlock; 11, derm or true skin; 12, coronary cushion; 13, laminal; 14, villous portion of the hoof matrix; 15, hoof; 16, the heel; 17, plantar cushion; 18, fibro-fatty cushion of the fetlock; 19, bare patch with thickened skin covering or "spur." (After *Flower*.) The corresponding parts of A and B have the same numbers.

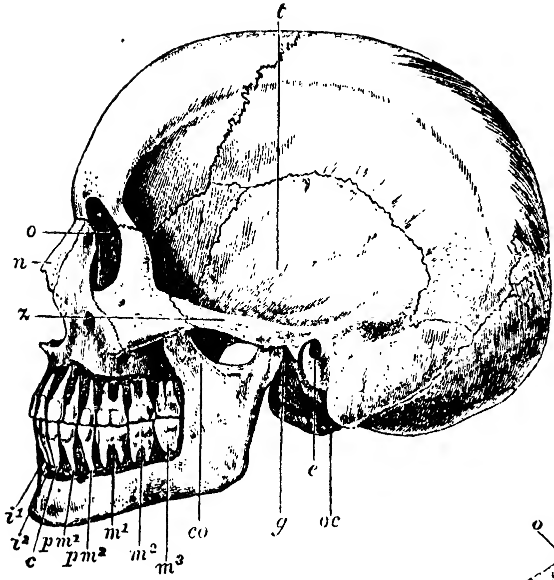
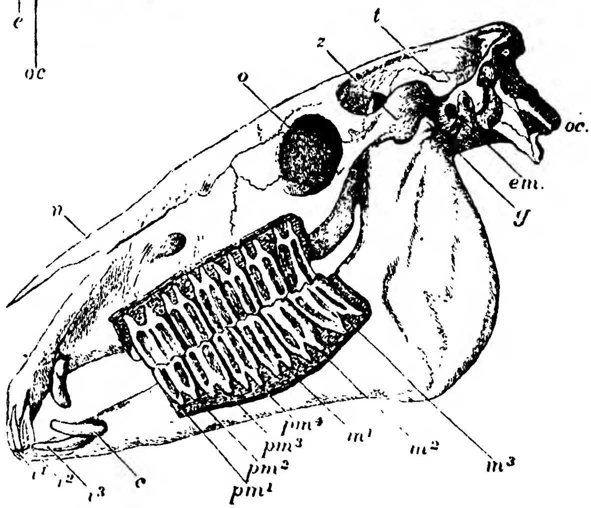



FIG. 168.—Skull of Man and (below) Horse.

Side view with part of the bone removed so as to show the whole of the teeth. The same letters refer to the same parts in both. *n*, nasal bone; *o*, eye; *z*, zygomatic arch; *t*, temporal fossa; *oc*, occipital condyle; *e* or *em*, external opening of ear; *g*, glenoid fossa for articulation of the lower jaw. Teeth: *i*, incisors; *c*, canine; *pm*, premolar; *m*, molar. (After *Flower*.)




leg stands almost perpendicularly over the foot. Both hind and fore limbs have obviously a similarity of plan. The thigh-bone, or femur, corresponds to the shoulder-bone, or humerus; the two shank-bones (tibia and fibula) to the two arm-bones (radius and ulna); the ankle-bones (tarsals) to the wrist-bones (carpals); the foot-bones (metatarsals) to the hand-bones (metacarpals); and lastly, each toe-bone corresponds to a finger-bone. The wonderful modifications in these structurally similar limbs point emphatically to a common ancestral group as their one origin, which, as we have seen, was one of the five-toed, roof-headed amphibians (Stegocephala).

The fore limb of the whale looks like a paddle and is used as such, but underneath the skin we find it has a real hand and arm which bear a striking resemblance to those of man (Fig. 173).

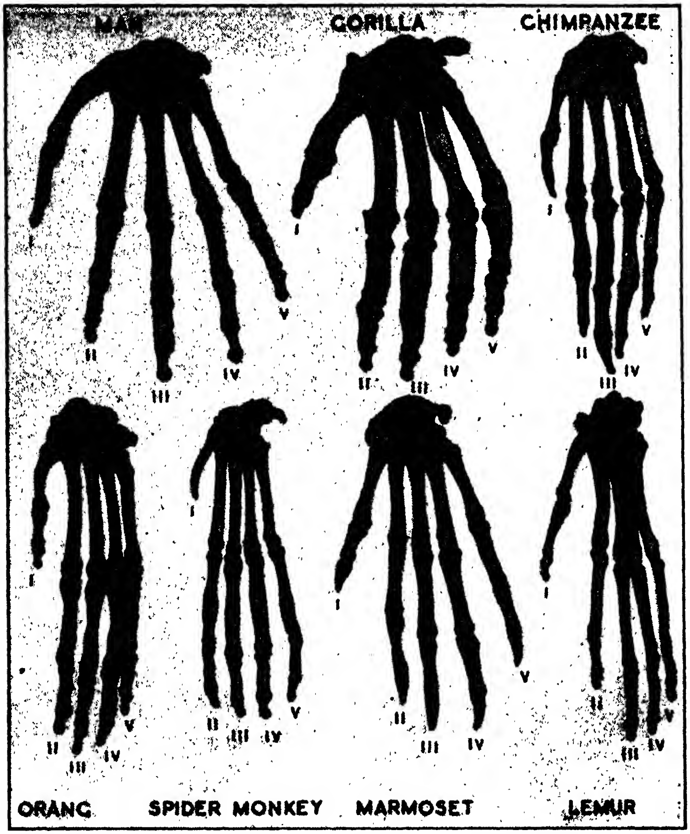



FIG. 169.—A Group of Hands. (The Roman figures represent the number of the finger, as in the case of the toes in (A), Fig. 166.)

There are few better ways of learning Evolution than that of examining some one organ in its various modifications and adaptations.

Limbs were first evolved in the earliest shark-like fishes (*Selachii*). From these they have been inherited by all the higher vertebrates — first as polydactyle (or many - fingered) *fins*, afterwards as pentadactyle (or five - fingered) hands and feet. The breast-fin, or fore limb, was originally just the same in structure as the belly-fin, or hind limb. The primitive form of the limbs, as found in these earliest fishes, is still to be seen in the Australian dipneust—the Ceratodus, or Burnett salmon—(Fig. 94, p. 92) whose paired fins are flat, oval paddles supported by a biserial cartilaginous skeleton (Fig. 174, I). The broad breast-fin of our shark-like, or Selachian, ancestors lost all the radii on one side, and many, but not all, of those on the other. The fin-stem became the arm, and the remaining radii the " hand," of the terrestrial vertebrate (Fig. 174, II, III).

Careful comparison of the fore limb of Ceratodus, the shark (Fig. 174), the amphibian, gorilla, and man (Fig. 175) will furnish you with a good idea of how the limbs of animals arose from the fins of fish.

At about the end of the sixth week the human embryo is roughly half an inch long, has a well-marked tail, and *webbed* limbs. These first appear as " limb-buds," which are outgrowths, not, as was formerly thought, of the vertebral system, but of a membrane called the *Somatopleure* that envelops the whole body; they are, in fact, a specialized portion of a continuous lateral fin-ray fold. This fold ultimately disappeared except at four sites, where pieces of it remained as the paired pectoral and pelvic fins of the fish, and these, in their turn, became later modified into the arms and legs of terrestrial vertebrates.

Man has many structures, known as " rudiments " or " vestiges," which are no longer of any use to him. The ears in Fig. 176 show remarkable points of similarity; for instance, that of the human fœtus closely resembles that of the orang, while the two ears at the bottom left hand of the figure show ape-like features in the small lobes and pointed margins. It will be remembered that the whole of the shell (*pinna*) of the ear in man is the useless vestige of a once very mobile organ.

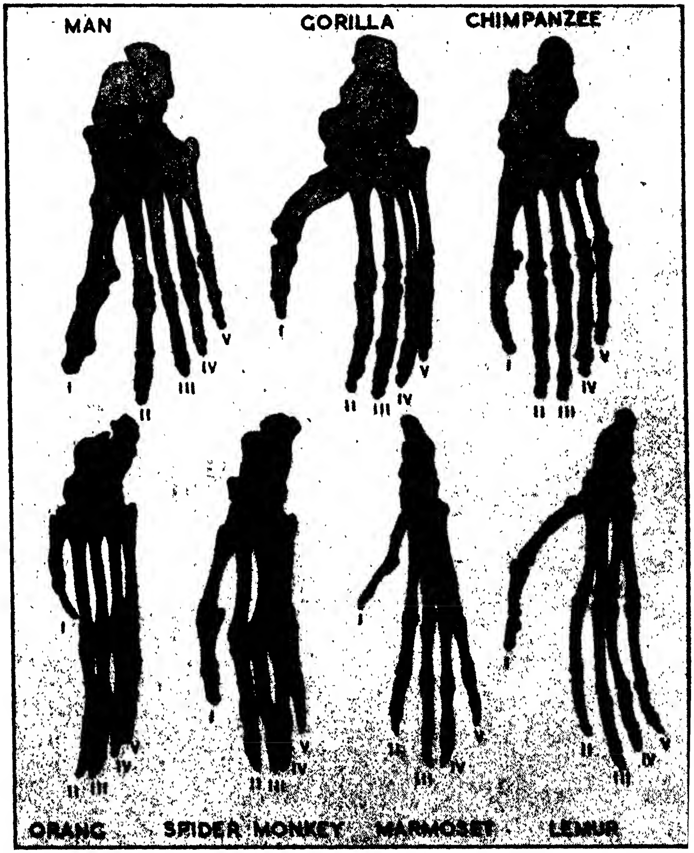



Fig. 170.—A Group of Feet. (The Roman figures indicate the number of the toe.)

The drawing of a fœtal orang shows a much earlier stage of the pointed ear (Fig. 177). Alongside it is shown a

human ear with the very interesting point, marked *a*, known as the Darwinian tubercle. It is more in evidence at birth than in later life, and in men than in women, and is the relic of the turned-over pointed tip of the common ancestor of man and ape.

Grown-up man presents rudimentary hair over most parts of the body.

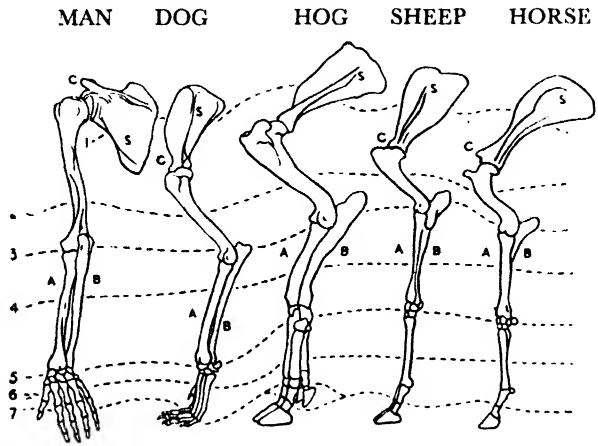



FIG. 171.—A Series of Fore Limbs. *Sc*, shoulder blade; *c*, coracoid process; *a*, *b*, bones of fore-arm; line 3 passes through the elbow joint; 5, through the wrist; 6, through the bones of the hand; 7, through bones of the fingers.

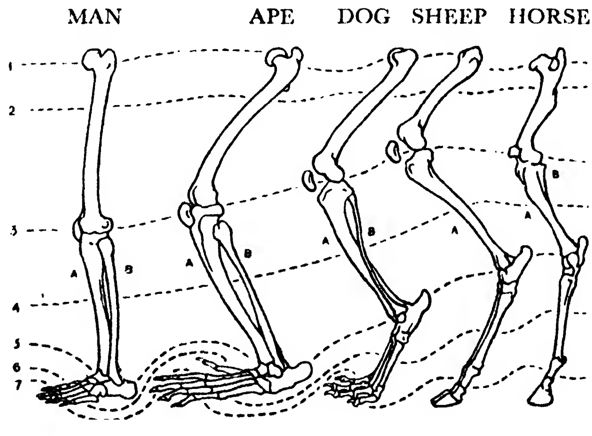



FIG. 172.—A Series of Hind Limbs. The top is the hip-joint; line 2 passes through the femur or thigh-bone; 3, through the knee; 4, through bones of leg; 5, through the ankle; 6, through bones of the foot; 7, through bones of toes.

In the case of the arms it is peculiar, for the hair on both the upper and lower arm is directed *to* the elbow. This curious disposition of the hair is a feature common to man and the apes (Fig. 178), and has been brought about through the habit of simians when sitting in the rain of placing their hands above the head. As observed by Wallace, the upper limbs are thus made to act as a thatch to throw the water clear of the body. The

direction of the hair tracts, generally, on the human body constitutes remarkable evidence of descent from hirsute arboreal ancestors.

We will next look at the comparative anatomy of the inside of the ear. The general arrangement is shown in Fig. 179. The origin of the little bones inside the ear is only explicable in terms of Evolution. They are named, from their shape, the *Malleus* or hammer, the *Incus* or anvil, and the *Stapes* or stirrup bone. They are in reality the discarded remains of the old gill-arches put to new uses; the hammer and anvil being parts of the first gill-arch, the stirrup of the second. These bones, the tiniest in the body, have had a more chequered career than perhaps any other part of the skeleton, yet their position is so sheltered from the storm and stress of an ever-changing environment that they have preserved throughout the ages a most remarkable similarity in widely different groups of animals (Figs. 180 to 183). The hammer-anvil joint was formerly the jaw-joint of the shark-like fishes, while in the still more remote past these bones formed a part of the gills used in breathing.

Fig. 184 is the view we should have if we took a brain out of the skull and turned it over. In the hinder part may be seen the cut ends of the spinal cord and nerves that connected the organ with the rest of the body; and in the central part the cut end of the left olfactory nerve and of both optic nerves.

Fig. 185 shows the brain as it appears from the side. It rises from a stalk where the spinal cord joins the brain. The horizontally-shaded mass completely covered by the hinder part of the cerebrum is called the "little brain" or cerebellum.

Fig. 186 is a view of the inner aspect of the right hemisphere. The curved area marked CC is the *corpus callosum*, or great commissure, that joins the two hemispheres together.

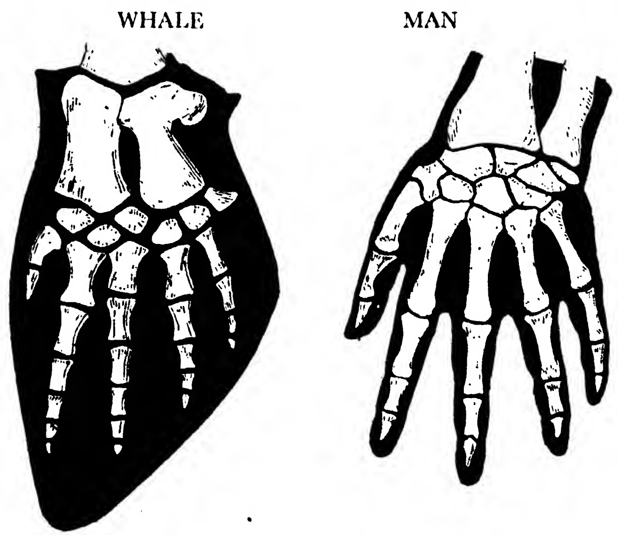



FIG. 173.—Paddle of a Whale and Hand of Man.

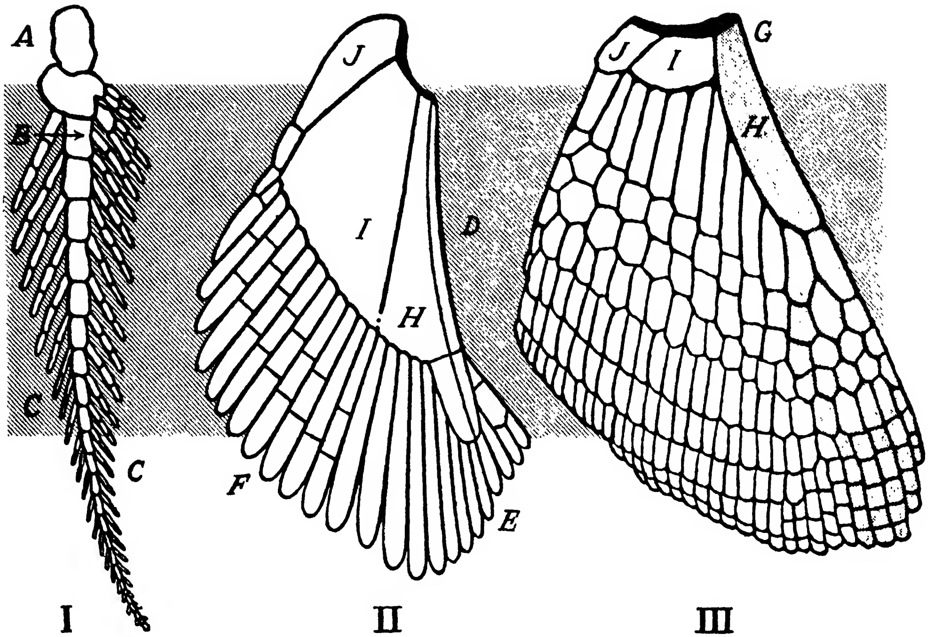



FIG. 174.—Three Breast-fins. I: Skeleton of the breast-fin of the dipneust, Ceratodus (*see* Fig. 94, p. 92); *A*, *B*, cartilaginous series of the fin-stem; *C*, *C*, cartilaginous fin-radii. II: Breast-fin of early shark. The radii of the median fin-border (*D*) have nearly all disappeared; a few only (*E*) are left; *F*, radii of the lateral fin-border; *H*, metapterygium; *I*, mesopterygium; *J*, propterygium. III: Breast-fin of a young shark. The radii of the median fin-border have wholly disappeared. The shaded part on the right is the section that persists in the five-fingered hand of the higher vertebrates; *G*, the three basal pieces of the fin; *H*, *I*, *J*, same as in II; *H* is the rudiment of the humerus. (*Gegenbaur.*)

Fig. 187 tells its own story. Note that in all the Primates (E—M) the cerebral hemispheres cover the cerebellum; in lower mammals (A, B, C, D) the little brain is not so covered.

Observe also in the brain (Fig. 188, I) of that very primitive mammal the duck-mole (Fig. 116) how smooth it is, and the relatively large size of the "smell-centre" (B) and its uncovered cerebellum (A). The brain of the kangaroo (Fig. 188, II), while smoother than that of man, is more convoluted than the duck-mole's. The cerebral fissures, so characteristic of human beings, are beginning to appear. The brain of the human fœtus (Fig. 189, B) is also, as we should expect, smooth. The brain of an *adult* Midas, one of the flat-nosed South American monkeys (marmosets) is also shown (A), and it will be seen that each presents the same well-marked Sylvian fissure.

The comparative series of brains given in Fig. 190 (p. 185) shows progressive consolidation and enlargement as we pass up the animal scale.

I is the brain of the fish; the cerebellum (CB) is fully exposed, while the olfactory lobes (OL) are relatively very highly developed.

The optic lobes (OP) are connected with the eyes and subserve vision. Without this connection we should not be able to see.

Fig. 192 shows three early stages of chicken brains, and helps us to understand how our organ of thought begins. In I we observe that the spinal cord, which runs nearly the whole length of the body, expands into a bulge at the top or fore end, just as it does in the Ascidian and Amphioxus (see pages 86 and 87).

In II it has divided into three round bodies, the fore- (*v*), mid- (*m*), and hind-brain (*h*); this is the *permanent* stage of some of the lower fishes.

In III the appearance of an intermediate- (*z*) and after-brain (*n*) brings the number of these small bodies up to five, which, as we have just seen, is the number of brain-parts in the higher fishes. The brain of a chicken or of a man passes through similar stages to those passed through by the Ascidian, Amphioxus, and fishes! In Fig. 193 the development of the embryo chick's brain is carried a step farther.

Notwithstanding the overwhelming evidence of the evolution of

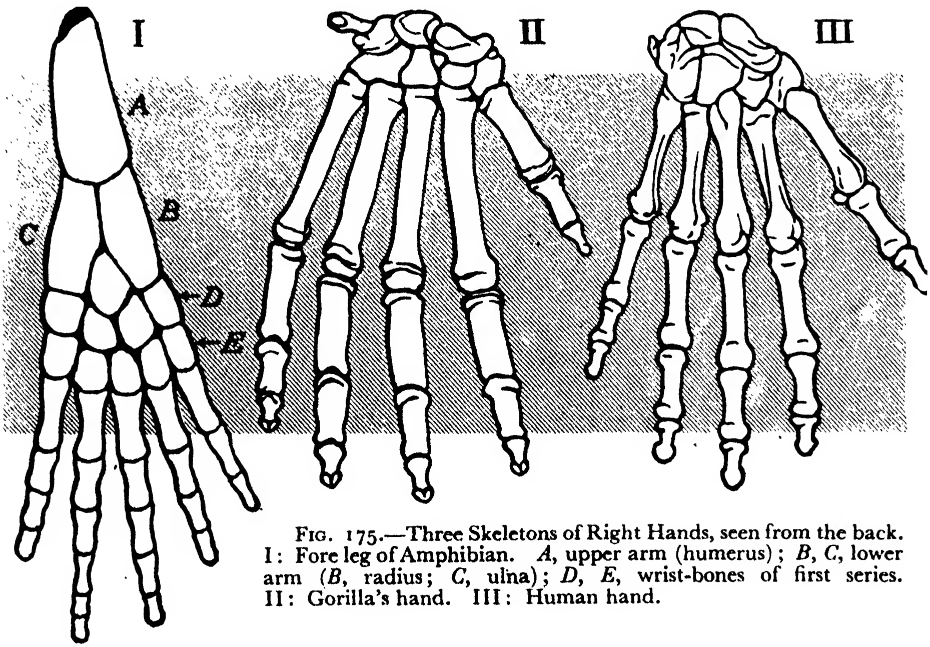



FIG. 175.—Three Skeletons of Right Hands, seen from the back. I: Fore leg of Amphibian. *A*, upper arm (humerus); *B*, *C*, lower arm (*B*, radius; *C*, ulna); *D*, *E*, wrist-bones of first series. II: Gorilla's hand. III: Human hand.

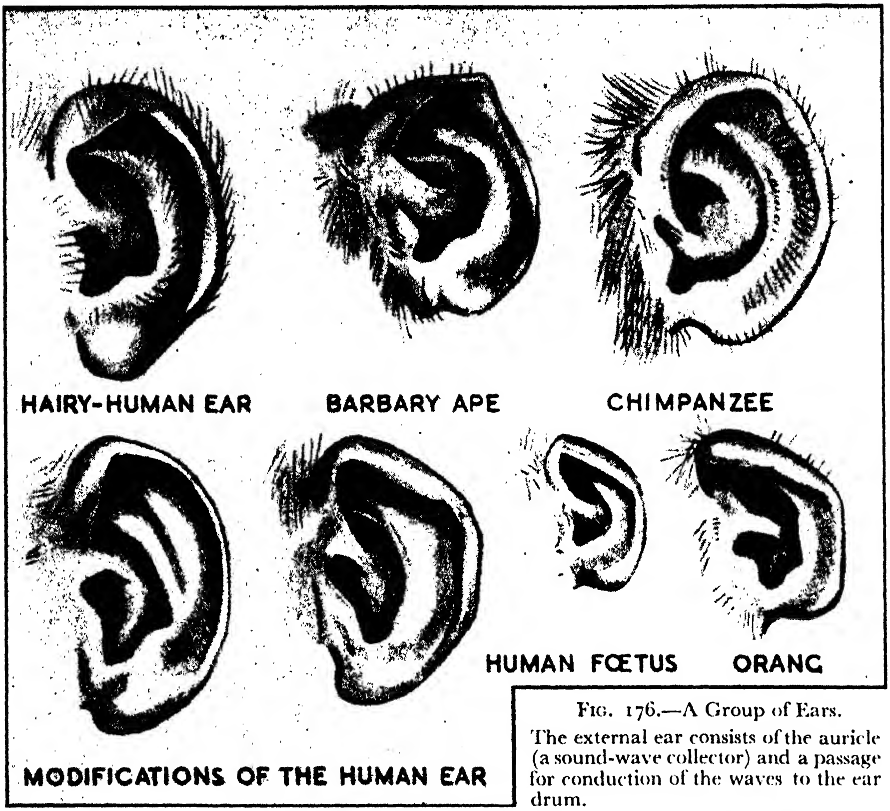



FIG. 176.—A Group of Ears.
The external ear consists of the auricle (a sound-wave collector) and a passage for conduction of the waves to the ear drum.

the human brain and its remarkable resemblance to that of the higher ape, the Special-Creationists persisted in saying: "It is only an outside resemblance. Cut into it, and you will find most important points of difference." So Huxley dissected the

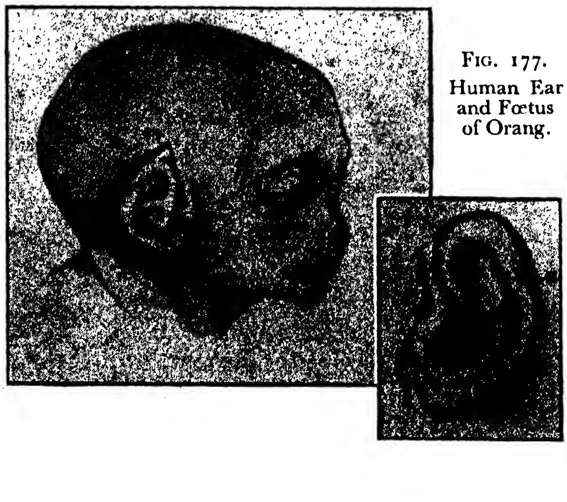


FIG. 177. Human Ear and Fœtus of Orang.

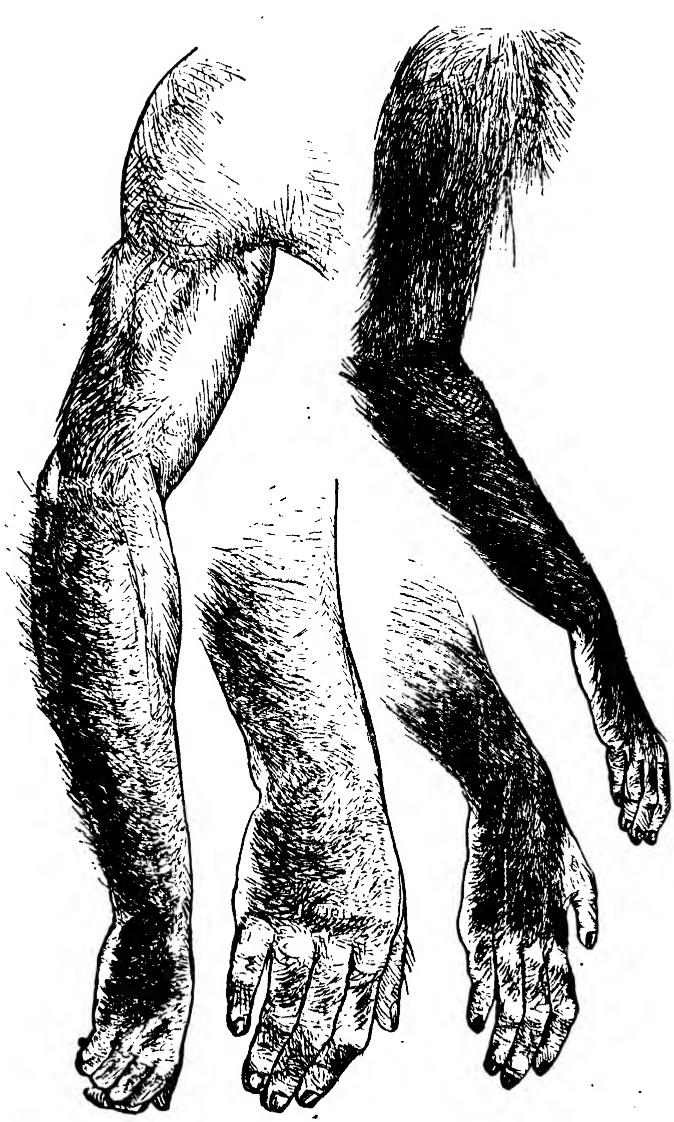


FIG. 178.—Hair Tracts on Arms.

(Left) Man. (Right) Male Chimpanzee.

Note the convergence of hairs towards the point of the elbow —an evolutionary device to throw rain water clear of the torso when the hands are placed over the top of the head while rain is falling and the animal is crouching.

brains of apes[1] to see. It had been seriously maintained by certain skilled anatomists that the ape had no posterior lobe (Fig. 194) (*a*), nor posterior cornu (horn) (*c*), nor hippocampsus minor (*x*). Huxley, and independently Sir William Flower, showed them to be among the most constant parts of the ape's brain, and always in the same position as in the brain of man! But even after the demonstrated

[1] Huxley's published researches on this question were: *Zoological Relations of Man and the Lower Animals*, *On the Brain of the Ateles Paniscus*, and *On Nyctipithecus*.

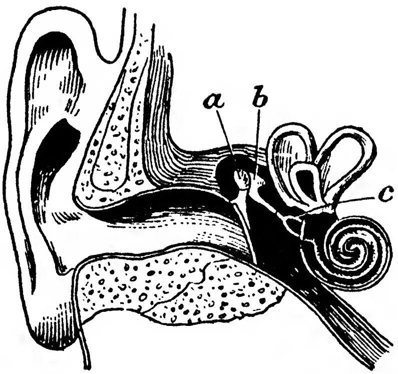



FIG. 179.—Diagrammatic Scheme of the Ear. (*a*) Malleus, (*b*) Incus, (*c*) Stapes.

The spiral arrangement is the *Cochlea* or true organ of hearing. The semicircles are the semicircular canals, three in number, one in each dimension of space. They are organs of balance. Most fishes and all higher animals have three, the lamprey has two, and the hag-fish, *Myxine*, but one.

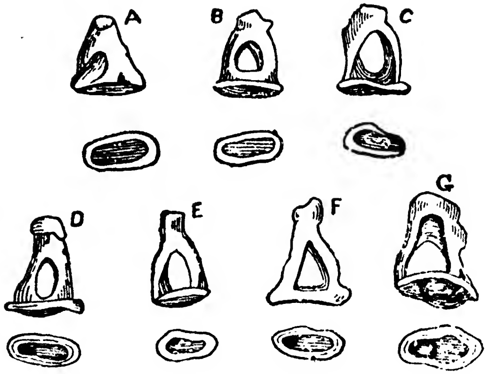



FIG. 182.—Stirrup bone of Ungulate Mammals. A, Hippopotamus; B, Hog; C, Musk-ox; D, Horse; E, Tapir; F, Rhinoceros; G, Elephant. The discs show the relative sizes of the bases of the stirrup-bones.

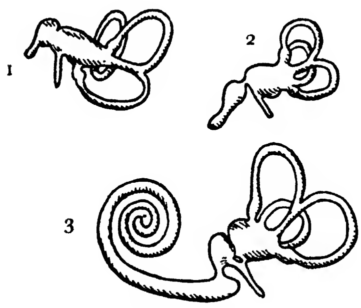



FIG. 180.—Diagrams of Auditory Labyrinth. (1) Fish, (2) Bird, (3) Mammal and Man.

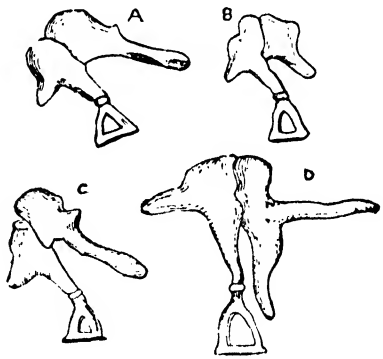



FIG. 183.—Ear-bones of Monkeys compared with those of Man. A, Lemur; B, Cebus (a platyrrhine monkey); C, Cercopithecus (a catarrhine monkey); D, Man.

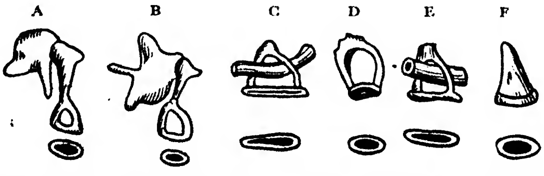



FIG. 181.—Earbones of: A, Bat; B, Shrew. Stirrup bone of: C, Mole; D, Hedgehog; E, Marmot; F, Sloth. The discs below indicate the shape of the foot of the stirrup. An artery is shown passing through the stirrup bone of the mole and marmot.

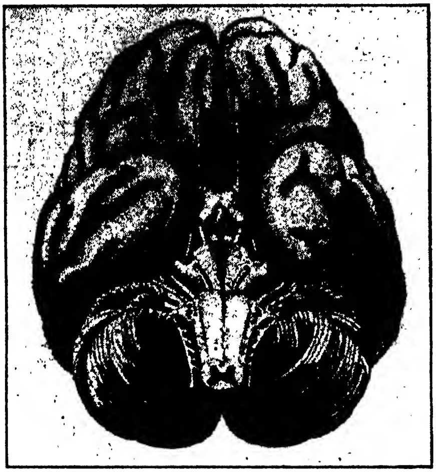


FIG. 184.—Human Brain from beneath.

existence, in the brain of the ape, of what had hitherto been claimed to be specifically human structures, there were still people who refused squarely to face the evidence and continued to deny Huxley's findings.

No biologist denies that the brain of man is a more highly developed organ than that of apes, but "in the brain," as Huxley said, "man differs *less* from the chimpanzee or the orang than these do from monkeys, and the difference

FIG. 185.—Left Hemisphere of Human Brain, outer aspect. The dark horizontally-lined mass is the cerebellum; note that it is completely covered by the cerebrum, or big brain, which is not the case with many lower animals, as shown in Figs. 187 and 188 (p. 184).

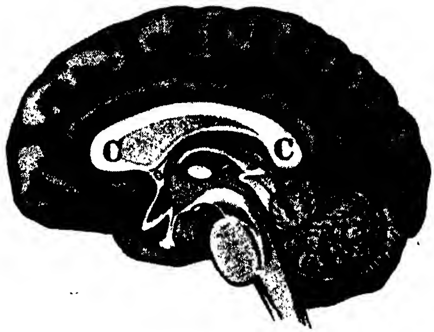



FIG. 186.—Inner aspect of the Right Hemisphere of Human Brain, showing the great nerve-band, or *corpus callosum*, CC, that links up the two hemispheres.

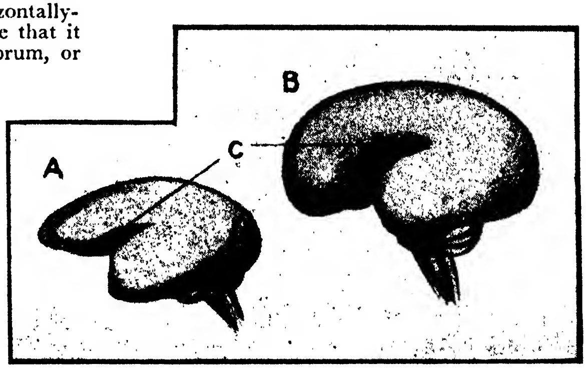



FIG. 189.—External Surface of the Left Hemisphere of (A) an adult marmoset, Midas, (B) human fœtus (five months). (C) Sylvian fissure.

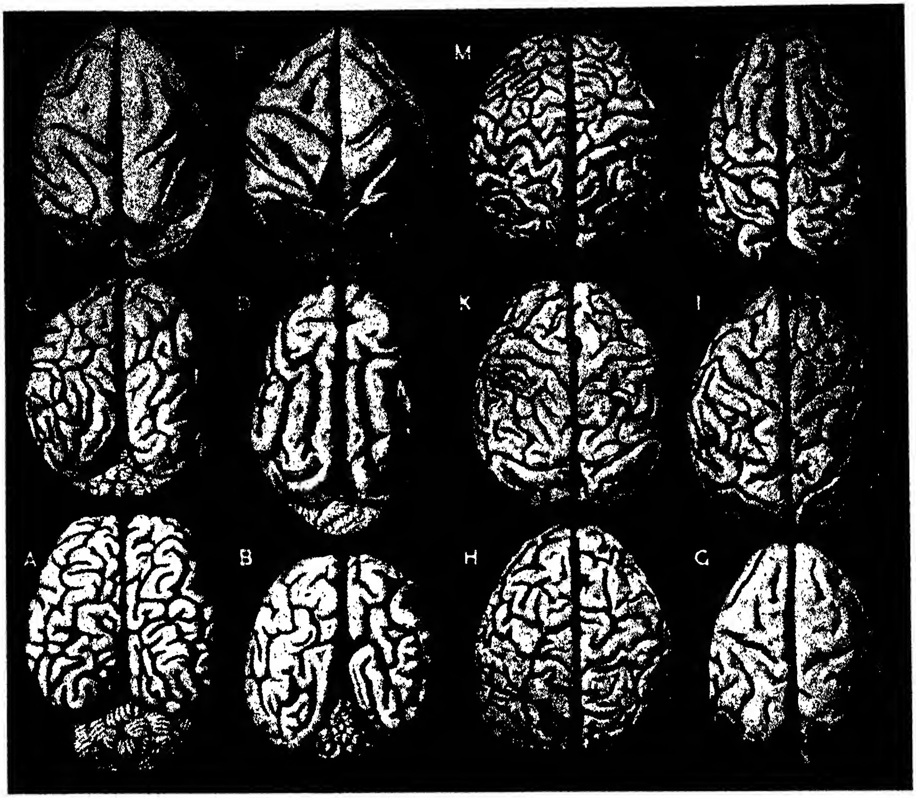



Fig. 187.—Twelve Mammal Brains. A, giraffe; B, seal; C, dolphin; D, lion; E, *Semnopithecus* (ape); F, *Cercopithecus* (monkey). Six Brains of Apes and Men. G, gibbon; H, chimpanzee; I, orang; K, gorilla; L, Bushman; M, civilized man.

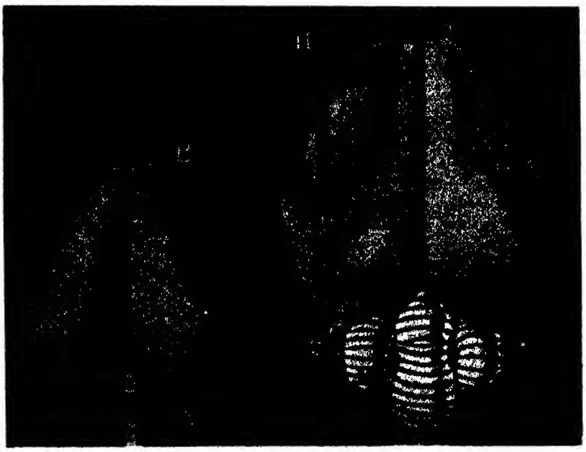


Fig. 188.—I, brain of the Duck-mole (*Ornithorhyncus*), dorsal view, natural size; A, cerebellum; B, olfactory lobes. II, kangaroo (*Macropus*). Note the scanty feeble convolutions in the kangaroo, a mammal lower than the Eutheria or placental mammals, but higher than the Prototheria, or egg-laying mammals, of which the duck-mole is a representative with a brain that is smooth and devoid of any convolutions.

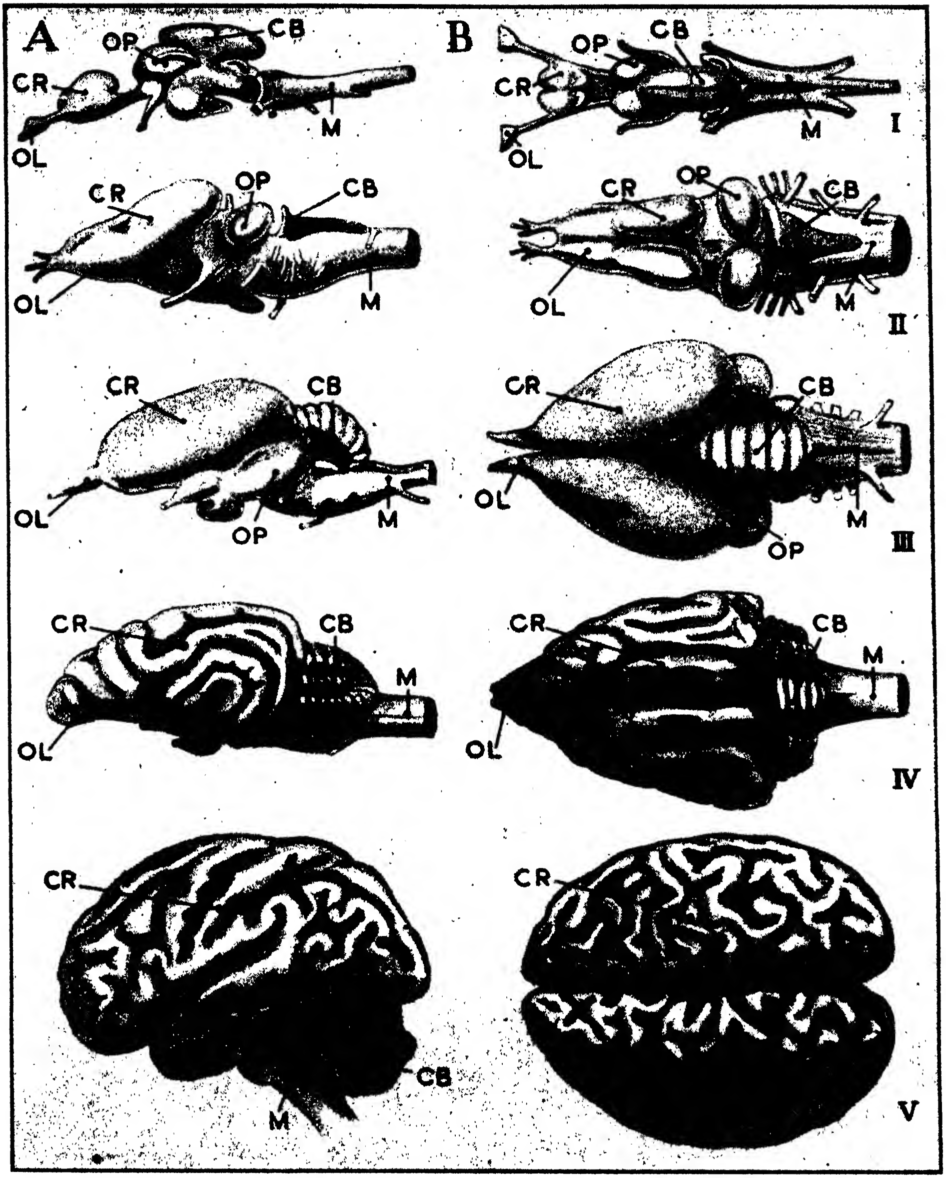



FIG. 190.—Comparative Series of Brains. A, side-view; B, seen from above. I, fish; II, reptile; III, bird; IV, mammal; V, man. M, medulla; CB, cerebellum; OP, optic lobes; CR, cerebrum; OL, olfactory lobes. Note the importance of the "smell-brain," or olfactory lobes, which is greatest in the fish and least in human beings.

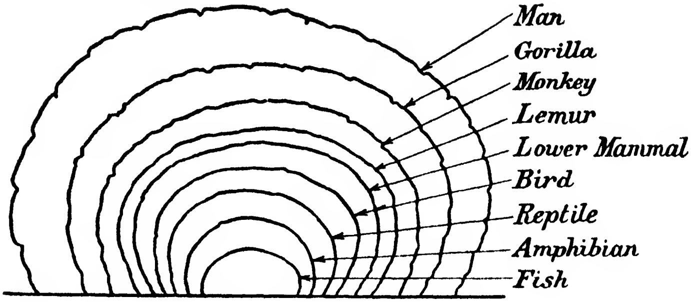



FIG. 191.—Schema to illustrate relative sizes of Brain in different classes of Vertebrates.

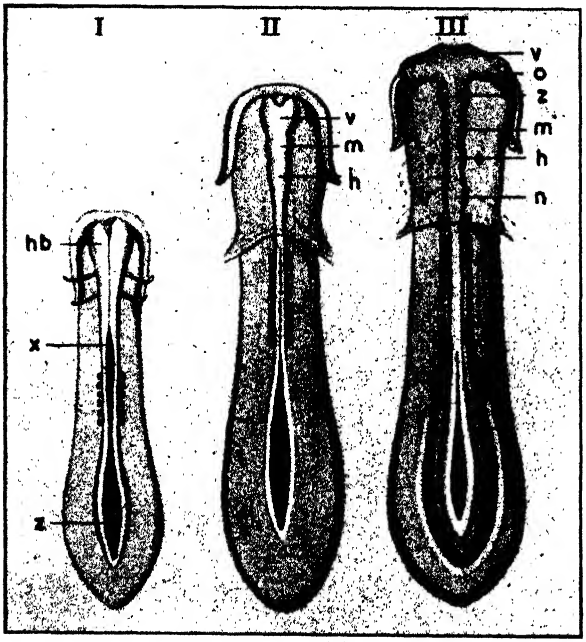



FIG. 192.—Embryonic Chickens in three successive stages of development (dorsal view), magnified about twenty times. I, brain a simple vesicle (*hb*). Medullary furrow still wide open from *x*; much enlarged behind at *z*. II, brain divided into three vesicles: *v*, fore brain; *m*, middle brain; *h*, hind brain. III, brain divided into five vesicles: *v*, fore brain; *z*, intermediate; *m*, middle; *h*, hind; *n*, after brain; *o*, optic vesicles.

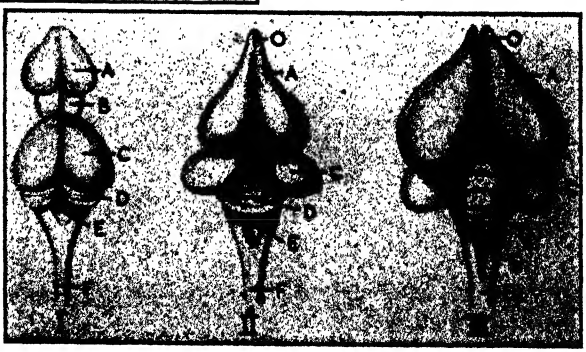



FIG. 193.—Brains of Embryo Chicks. I, 8 days; II, 16 days; III, 20 days. Letters same in all—O, olfactory lobes; A, hemispheres of the brain; B, optic thalamus; C, optic lobes (corpora bigemina); D, cerebellum; E, fourth ventricle; F, spinal cord.

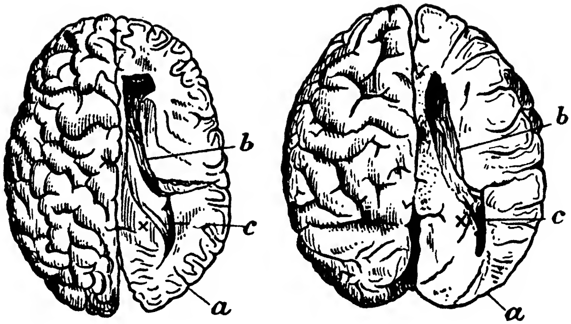



FIG. 194.—Cerebral Hemispheres of Man and Chimpanzee dissected. *a*, Posterior lobe; *b*, lateral ventricle; *c*, posterior cornu; *x*, hippocampus minor. The figure shows the hippocampus minor in the ape's brain, the presence of which had been vehemently denied by Prof. Owen and other anti-evolutionists until Huxley disproved their claim.

between the brains of the chimpanzee and of man is almost insignificant when compared with the difference between the chimpanzee brain and that of a lemur."

The late Professor Elliot Smith and Sir Arthur Keith—leading modern authorities in comparative anatomy—are agreed that there is no part of the human brain that is not present in that of the simian. "No structure found in the brain of an ape," says the former of these two scientists, "is lacking in the human brain; and, on the other hand, the human brain reveals no formation *of any sort* that is not present in the brain of the gorilla or chimpanzee. . . . The only distinctive feature of the human brain is a quantitative one." Not only man's brain, but his bones, muscles, nerves, and blood-vessels—in fact, all his organs—are almost exact replicas of the corresponding parts in the ape.

Fig. 195 shows the tops of three skulls drawn from the actual specimens. On the left is the skull of a chimpanzee, in the middle the skull of the "ape-man" Pithecanthropus (partly restored), on the right the skull of a

FIG. 195.—Comparison of the Tops of Skulls. On the left is the skull of the chimpanzee; in the middle, that of Pithecanthropus, the ape-man of Java; on the right, a skull of modern man. The slanting line across the skull is an indication of the relative volumes of the three brains.

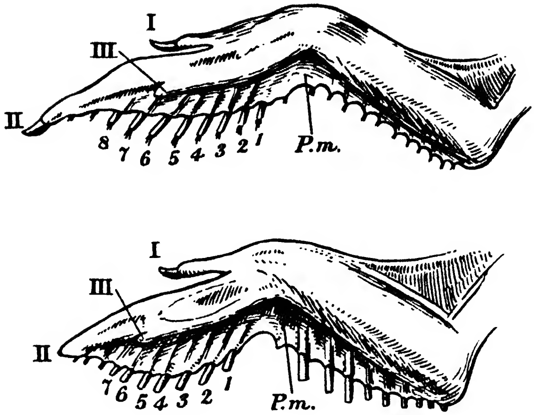
FIG. 195A.—Pithecanthropus.
*From* H. R. Knipe's *Evolution in the Past.*

modern man. The line (which goes through corresponding points in each of the three skulls) shows how much shallower is the dome of the ape's skull than that of man, while the middle skull (Pithecanthropus) exhibits a shallowness that is a mean of the other two. (See also Fig. 191.)

We may close this chapter with a reference to a very remarkable bird that one might almost describe as a still living reptile-bird. The crested Hoatzin (Fig. 196), or Stinking Pheasant, as it is called (on account of the strong musk-like odour given off by the adults), haunts the dense thickets bordering the lagoons, creeks, and rivers of the Amazon valley.

Mr. Pycraft, the great

FIG. 197.—Right Wing of a young Hoatzin, showing how the second digit (II) is produced beyond the *ala membrana* (*P.m.*), and that the development of remiges 8–10 has been arrested, so as not to interfere with the freedom of the long finger when climbing. (Below) Right wing of nestling of Common Fowl. Owing to the exchange of an arboreal for a terrestrial habitat, the manus is gradually shortening. The pollex (I) only retains the claw. The second digit projects but slightly beyond the *ala membrana*, but the development of the most distal remiges is still arrested.




authority on birds, says: "In the wing of this nestling (Fig. 197) we have a revelation of profound importance, for, so it seems to me, through it we get a glimpse into the phylogeny, not only of its immediate allies (the *Gallinæ*), common fowls, but possibly into that of the whole class of birds."

The Hoatzin lives in trees, rarely, if ever, coming to the ground, and its call is a reptile-like hiss. Its young can see, swim, and climb about, as soon as hatched. In climbing, the young not only use their beaks (in parrot-like fashion) and their large feet for grasping, but they also use their wings as hands for holding on to branches. They are able to do this by means of two clawed finger-tips that protrude from each wing. So when Cuvier declared that birds were really four-legged animals he was quite correct so far as the young Hoatzin is concerned. As the bird grows, its claws disappear, while its feathers—specially arrested in growth during early life so as not to impede climbing—come to perfection, and the bird gets its full wings and is able to fly. Here, then, in the American forests, we can see a truly living fossil, a creature that begins life in a clumsy, four-footed reptile-like manner and ends by flying about as a bird! In 1931 C. W. Webb succeeded in bringing a Hoatzin from Brazil, and in 1933 an Ornithorhynchus from Australia, both of which "living fossils" he presented to the Zoological Gardens of London.

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FIG. 196 (Left).—The Stinking Pheasant, or Hoatzin (*Opisthocomus cristatus*). Cf. Fig. 197. The second finger in birds is only rarely clawed; this occurs in the young of the hoatzin, which use this claw especially for climbing about the brush almost as soon as they leave the egg. The American vulture, the kiwi, emu, and cassowary, also possess a clawed index finger. The hoatzin would seem to be fast becoming a flightless bird, for it is most loth to take to flight in the air.

# CHAPTER NINE: EMBRYOLOGY AND RUDIMENTS

WE have seen from the evidence of astronomy that evolution is far from being confined to living things. Next we have learnt from geology that many species of animals have disappeared, while others have altered in form, and all are traceable back to one ancestral group; in fact, that, as the rocks themselves have evolved, so have the animals whose skeletons they preserved. The farther back we go into the history of the past, the less are the ancient animals like our modern ones; and the older the skulls of men, the more ape-like they are.

Zoology shows us how impossible it is to draw a sharp line between one group of animals and another. In the last chapter we saw agreements of plan of structure explicable only on the supposition that all animals have come by a long series of changes from some common ancestor.

There is stronger positive evidence of evolution in embryology than elsewhere. (Embryology is the science which traces the growth of any animal, *before birth*, from a cell, about 120th of an inch in diameter, to its relatively complete form when it is born.) Such difficulties meet us when we consider rudimentary structures that no explanation can possibly be given of them except that furnished by Evolution, but until young people are made familiar with the methods of science, it will be a hard task to teach the older ones anything about embryology, since it deals in many cases with structures that can be seen only through a microscope.

Embryology furnishes us with a record of animal forms and of the marvellous likenesses existing between them. Every animal, from the lowest up to man, contributes its page of the revelation of the past. The largest and smallest, most hideous and most beautiful, the stupidest and wisest, all start life as a tiny cell and, for a longer or shorter period, pass through practically indistinguishable stages.

It is no matter of imagination; here we are face to face with the ever-recurring fact of our own growth from a single tiny cell. All men and women, great or small, and every other living creature, from sponges and worms to elephants and apes, began their life-history as two tiny single-celled organisms which mated to become a single fertilized ovum or egg-cell. This organism, so minute that 120 of them side by side would measure but an inch, holds within itself a marvellous future, which, in

man, may be that of a Shakespeare writing comedies and tragedies that stir the emotions of all civilized peoples, or a Florence Nightingale soothing the sufferings of the wounded on a battlefield, or an Einstein revolutionizing scientific conceptions of the universe, or a Winston Churchill welding diverse nations together in the face of fearful odds; or it may become plain Mr. Jones or Mrs. Smith pursuing quiet and uneventful lives; or, finally, it may turn into an Adolf Hitler wilfully inflicting unspeakable sufferings on the world.

The better to understand some of these living wonders we will begin with a study of a few of the lowest forms of life.

Fig. 198 shows the boundary wall, the thin threads of protoplasm and the nucleus that go to the make-up of a single hair-cell of *Tradescantia*, the Virginian spider-wort. The bodies at III are blood cells, and they look and behave just like amœbæ. Protoplasm is the living part of the cells of all animals and plants; in general appearance it is not unlike the transparent portions of the jellyfish and frog-spawn. A complete division of a cell such as that of *Tradescantia* (Fig. 198, I) takes ninety minutes. But the cells constituting the smallest known (visible) living individuals, the *Bacteria* (Fig. 199)—some of which are less than the one-ten-thousandth of an inch—divide into two individuals once every twenty minutes or so. A single Cholera bacillus, for example, becomes 2, 4, 8, 16, 32, 64 bacilli in two hours. Given unlimited food supply, room, and powers of spread, a single bacillus would in one day develop a progeny of 1,600 trillion descendants with a total weight of one ton. In two days their weight would

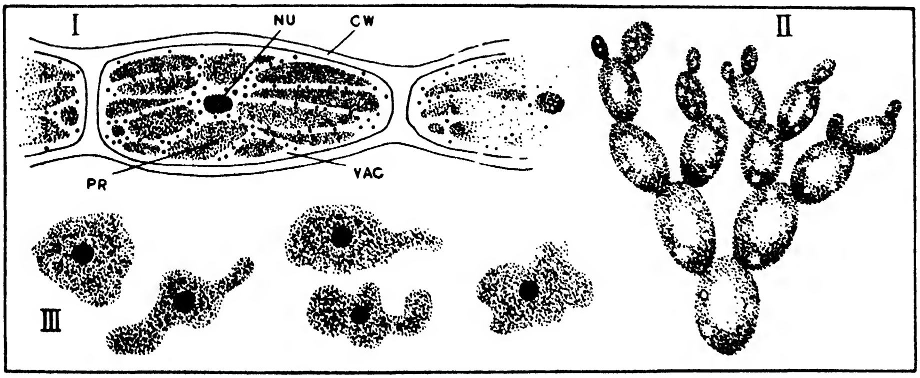



FIG. 198.—I, Cell, from filament of *Tradescantia*. The protoplasmic threads are light, and in them are contained the nucleus and chlorophyll granules. The spaces between the threads are filled by coloured cell-sap. II, Group of yeast cells, exhibiting active budding. III, White or amœboid corpuscles from the blood of a frog, showing changes of shape undergone during five minutes. NU, Nucleus; CW, Cell-wall; PR, Protoplasm; VAC, Vacuole.

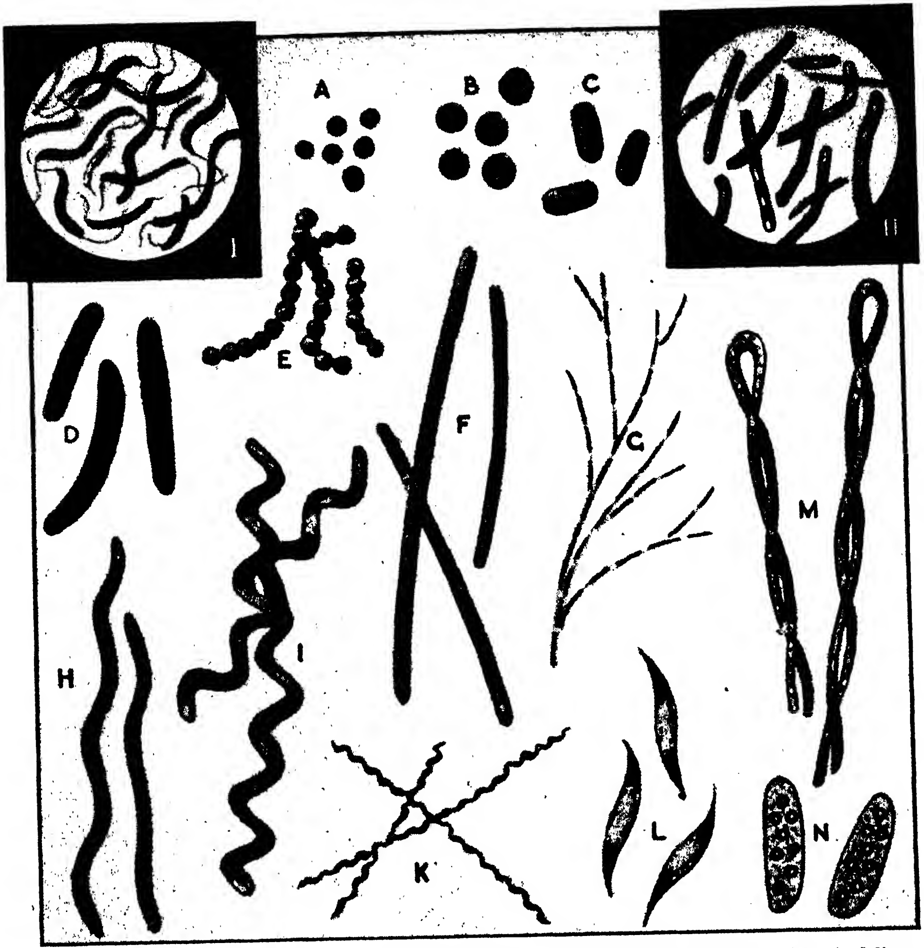



FIG. 199.—Forms of Bacteria. I, Cholera vibrios. II, Bacilli of Tuberculosis. A, Micrococcus; B, Macrococcus; C, Short Bacillus; D, Long Bacillus; E. Streptococci; F, Leptothrix; G, Cladothrix; H, Vibrio; I, Spirillum; K, Spirochæte; L, Very short Spirillum; M, Folded Spirillum; N, Very large Short Bacillus with sulphur granules. Many of these are harmless; others, especially E, H, and K, are dangerous.

far exceed that of the earth, which, you may (or may not) remember, amounts to 5,870 trillion ($5{\cdot}87 \times 10^{21}$) tons. In less than six months the whole visible universe would be solid with the protoplasm of the massed bacilli! Fortunately, such alarming geometrical rate of progression is checked, either by lack of food material or by the bacilli perishing, as did the unfortunate human beings in the Black Hole of Calcutta, through

accumulation of their own products of excretion. Bacteria exist almost everywhere if moisture and a favourable temperature of 32° F. to 160° F. are present. They soon swarm in millions in a single drop of organic fluid, such as blood, milk, urine, meat-juice, etc., if it is freely exposed to the air in which their spores float. Darken a room and allow a beam of sunlight to enter through a small aperture, and you will see countless myriads of floating specks. Each speck is, so to speak, a Zeppelin balloon, freighted with its minute invisible passengers—the spores of bacteria and other micro-organisms. It is due to the agency of *micro-organisms*, as the bacteria and their fellow-microbes are called, that our edibles " go bad " and give off an evil smell, and, if swallowed, afflict us with " ptomaine poisoning." It is the " toxines " which these creatures manufacture and set free in our blood that give rise to the characteristics of such diseases as influenza, glanders, malaria, sleeping-sickness, and so forth. These highly specialized disease-producing " germs," or microbes, have arisen by relatively rapid adaptation (indeed many of them are known to be far later products of Evolution than man himself) from harmless *prototrophic*—that is, mineral-feeding—bacteria. Fortunately the beneficent types of microbes vastly out-number the noxious kinds. Without the aid of bacteria the whole surface of the earth would soon be littered with the " corpses " of trees, flowers, elephants, mice, and men, for it is through their chemical handiwork that complex organic matter is returned into such simple compounds as water, carbon dioxide, nitrogen, free hydrogen, ammonia, marsh gas, and sulphuretted hydrogen—the end-products of lily or man. Without these end-products there could be none of that synthesis by plant protoplasm and sunlight whereby new life emerges. It is to the bacteria we owe the fertility of our soil, the flavour of our wines and butters, and the ripening of our cheese; they make our vinegar, " cure " our tobacco, sparkle our beer, tan our leather, prepare our indigo, enable our peas and beans to grow, and assist in the manufacture of our linen, jute, and hemp. So, while taking precautions to give the deadly microbes as wide a berth as possible by breathing fresh air, drinking pure beverages, and insisting on good sanitation and uncontaminated foods, let us ever remember that, as regards these invisible friends and foes, the net balance is on the credit side.

The Amœba (Fig. 200) is found in stagnant water. It seldom exceeds one-hundredth part of an inch, so is mostly invisible to the naked eye. It is a tiny shapeless blob of nearly colourless protoplasm. Amœba means " the changing one," and it is so called because in an active state

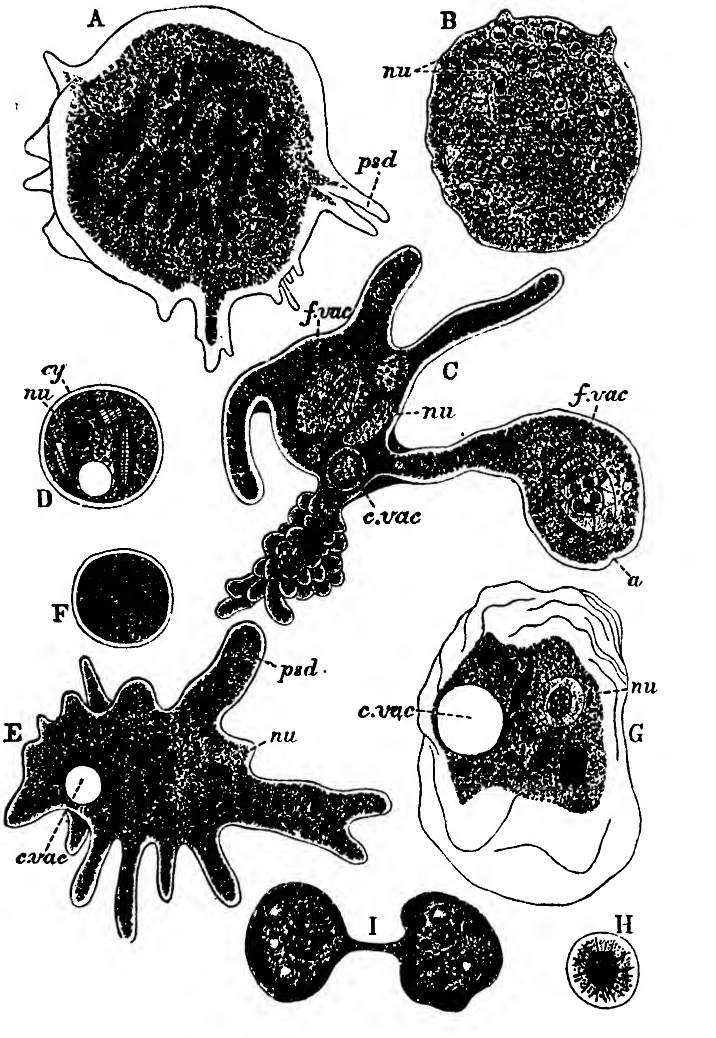



FIG. 200.—The Amœba. A, Amœba quarta, a living specimen, showing granular endosarc surrounded by clear ectosarc and several pseudopods (*psd*), some formed of ectosarc only, others containing a core of endosarc. The larger bodies are mostly food particles. This is enlarged 300 diameters. B, the same species killed and stained with carmine to show the numerous nuclei (*nu*). C, Amœba proteus, a living specimen, showing large irregular pseudopods, nucleus (*nu*), contractile vacuole (*c.vac*), and two food vacuoles (*f.vac*), each containing a small infusorium which has been taken as food. The letter *a* to the right of the figure indicates the place where the protoplasm has united round the prey to enclose the food vacuole. D, an encysted Amœba showing cell-wall or cyst (*cy*), nucleus (*nu*), clear contractile vacuole, and three diatoms ingested as food. E, Amœba proteus, a living specimen, howing several large pseudopods (*psd*), single nucleus (*nu*), and contractile vacuole (*c.vac*), and numerous food particles. Enlarged 330 diameters. F, nucleus of the same after staining, showing deeply-stained granules of chromatin, surrounded by a distinct membrane. Enlarged 1,010 diameters. G, Amœba verrucosa, living specimen, showing wrinkled surface, nucleus (*nu*), large, contractile vacuole (*c.vac*), and usual ingested organisms. Englarged 330 diameters. H, Nucleus of the same, stained, showing chromatin aggregated in the centre to form a nucleolus. Enlarged 1,010 diameters. I, Amœba proteus, in the act of multiplying by binary fission. Enlarged 500 diameters. (From *E. J. Parker*.)

it is never the same shape for long together, for it is always pushing out some parts called pseudopods (false feet) and at the same time drawing in others.

The Hæmatococcus, sometimes called Protococcus (Fig. 201), is found in standing rain-water that has turned a greenish-red colour. The colour is due to the presence of small organisms, of which the Hæmatococcus is the commonest. Like the Amœba, it requires to be magnified some 900 times in order to be seen.

If this figure is compared with that of the Amœba, many points of resemblance will be seen; but the cell-wall of Amœba is probably nitrogenous, whereas this creature has its cell-wall formed of cellulose—a carbohydrate allied to starch, sugar, and gum. This indicates that, whereas Amœba is near the bottom rung of the animal ladder, Protococcus is near the bottom rung of the plant ladder.

We should note that, in Amœba, locomotion is performed by any part of the body which it can improvise, for the time being, into a simple kind of oar; in Hæmatococcus it is performed by a small part only—the flagella. We have here, therefore, the commencement of *specialization* manifesting itself as a *differentiation of structure and function*; or, in other words, a division of physiological labour.

The Springing Monad (Fig. 202) is partly plant, partly animal, and is much smaller than Amœba or Hæmatococcus, being only $\frac{1}{3000}$th of an inch in length. It presents points of advance over these, however, for it has distinct ends, and also a ventral and dorsal surface. It not only reproduces by simple fission, like Amœba, but also by *conjugation*, or

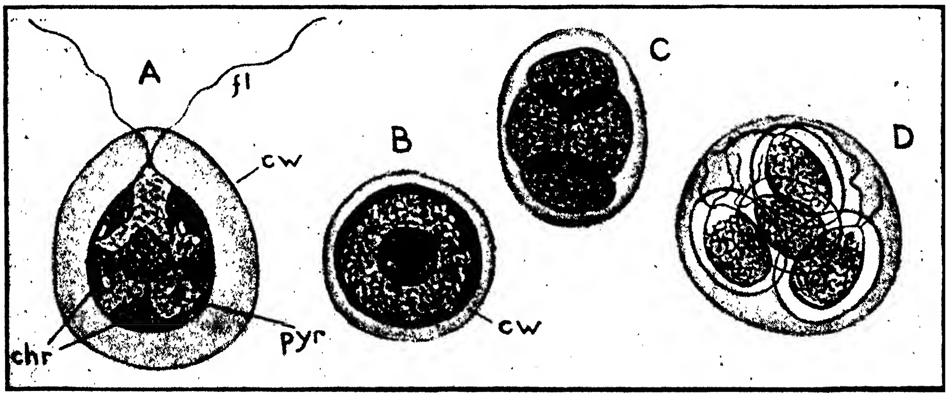



FIG. 201.—A, *Hæmatococcus Pluvialis*, mobile phase. Living specimen, showing protoplasm with chromatophores (*chr*), and pyrenoids (*pyr*), cell-wall (*c.w*), connected to cell-body by protoplasmic filaments, and flagella (*fl*). B, resting stage of the same; C, the same, showing division of the cell-body into four daughter cells; D, showing development of flagella before daughter-cells are liberated. Hæmatococcus lives on damp rocks, soil, trees, in ditches, ponds, water butts and roof-gutters. It is the cause of red snow above the snow line. It reproduces asexually, as shown at D, but also sexually by means of conjugating gametes.

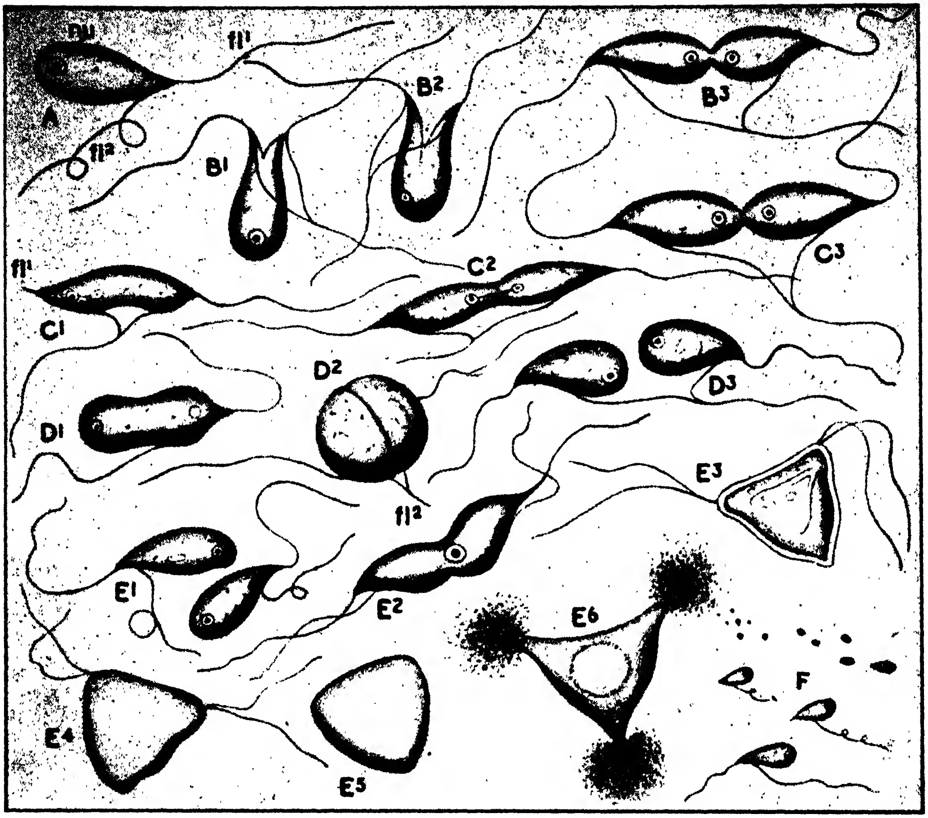



FIG. 202.—The Springing Monad, *Heteromita Rostrata*. A, living organism: *fl*², the coiled ventral flagellum by which the organism is anchored; *fl*¹, fully extended. B¹–B³, stages of fission, longitudinally, of the anchored form; C¹–C³, stages of fission, transversely, of same; D¹–D³, fission of the free swimming form; E¹, free swimming and anchored forms about to conjugate, till process is complete in E⁵; E⁶, the emission of spores; F, stages in the development of the spores. (After *Dallinger*.)

*amphimixis* (both mixed), two organisms fusing into one ($E^1$ to $E^5$) and then later dividing into two ($B^1$ to $B^3$), or remaining as one and throwing off "spores" ($E^6$). During *amphimixis* the smaller and more active participant is probably the male; the larger and more passive, the female. Euglena (Fig. 203) is another plant-animal, for it feeds like a plant in the day, and like an animal in the dark.

Fig. 204 exemplifies the varieties of form and phases among cells. In I and II (Fig. 205) we see the resting, passive, encysted phase; in III the explosive, reproductive phase, with the begetting of daughter-cells which at first are ciliated and extremely active, later sluggish and

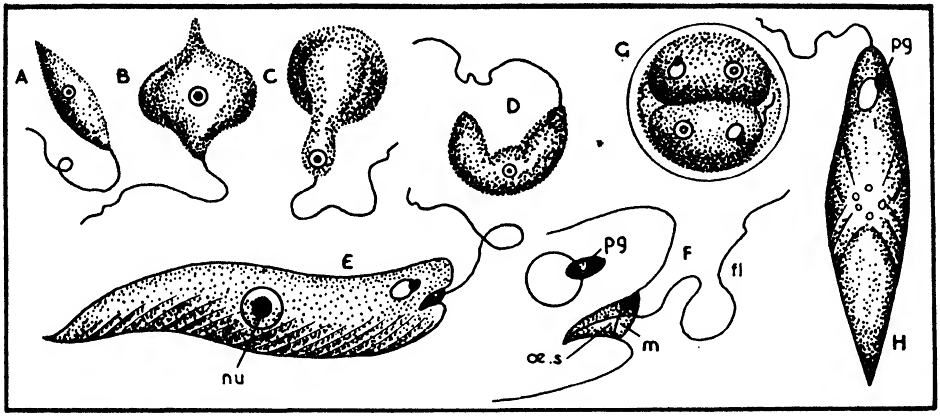



FIG. 203.—Euglena Viridis. A–D, living organisms, showing changes of form; E, enlarged view; F, enlarged view of *anterior* end, showing pigment spot (*pg*), mouth (*m*), gullet (*œ.s*); G, resting form after fission; H, active form. (From *Parker.*)

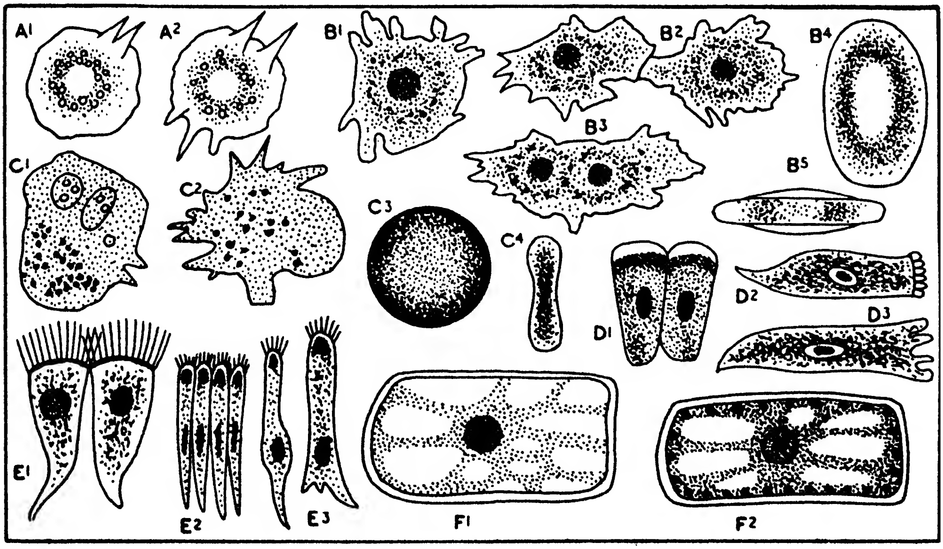



FIG. 204.—Typical Animal and Vegetable Cells. $A^1$–$A^2$, living leucocytes (blood corpuscles) of a crayfish. $B^1$–$B^3$, the same of a frog; $B^4$–$^5$, surface view and edge view of a red corpuscle of frog; $C^1$, $C^2$, leucocytes of newt (the black dots are particles of vermilion which have been ingested); $C^3$, $C^4$, surface and edge view of red corpuscle of man; all D and E are epithelial cells from intestines or mouths of animals; $F^1$, cell from root of lily; $F^2$, from leaf of a bean. (From *Parker.*)

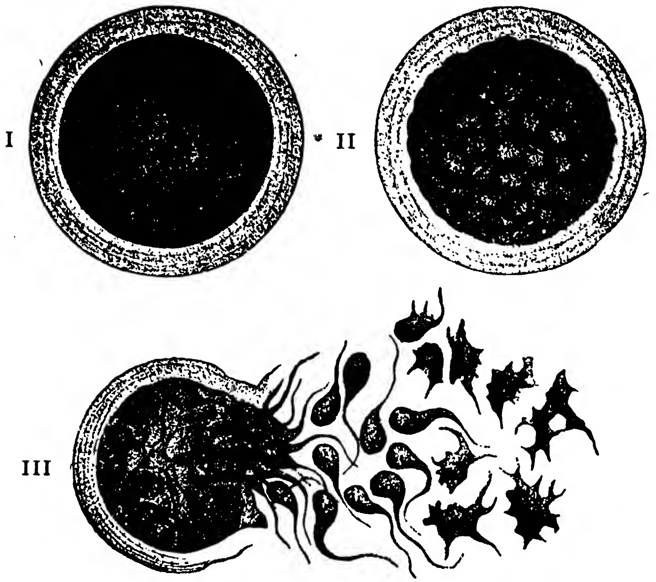



FIG. 205.—The Protomyxa, one of the primitive moulds, or Myxomycetes. I and II show it encysted: in II we see its division into numerous individuals within the cyst; III, the cyst bursts, the flagellate young rush out like so many minute tadpoles, but at once they become like Amœbæ, as seen on the right. (After *Geddes* and *Thomson.*)

amœboid. Passive cells show conservative accumulation of material and energy and, physiologically, are anabolic. (*Anabolism* stands for functions subserving self-maintenance; it is individualistic, is constantly building itself up, and characterizes *femaleness.*) On the other hand, small active cells show radical and lavish expenditure of material and energy and, physiologically, are katabolic. (*Katabolism* stands for functions of species-maintenance; it is altruistic, is constantly breaking down its own substance, and is characteristic of *maleness.*) The female ova of plants and animals are preponderatingly anabolic, while the male sperm-cells are preponderatingly katabolic. The human female ovum, or egg-cell, is a spherical lump of protoplasm about the $\frac{1}{120}$th of an inch in diameter, while the feverishly-active flagellated male cell is so tiny that thousands would be required to weigh down the female cell.

In Fig. 207 we see egg-cells from different animals, and it is only necessary to glance at them to see that the general arrangement is the same. Any one of these egg-cells, if fertilized (and by this process, remember, is meant entry into the egg-cell of *one* male cell and the fusion of its nucleus with the egg-cell nucleus, see *e.g.* Fig. 206), becomes the beginning of a new being, be it a thistle, oak, sponge, worm, cat, or man. Fig. 208 shows the human ovum highly magnified. Its *actual* size is that of one of the smallest visible dots inside the little dark circle representing the nucleolus.

Within the nucleus of all animal and plant cells are certain very important constituents known as the *chromatin bodies*. It is they that hold and pass on, so to speak, the hereditary elements. When the parent-cell divides into two daughter-cells, the chromatin bodies, passing into these, carry with them the material basic entities that enable descendant cells to imitate and repeat the form, features, characters, and characteristics of former cell generations; they are, in a word, the *vehicles of heredity*. As a rule these chromatin bodies lie inside the nucleus as organized aggregations called *Chromosomes*. Both words are from the Greek *Chroma* (colour), because a feature of chromatin is its great avidity to take up dark aniline dyes and so to stand out under the microscope in marked contrast to the rest of the cell (Fig. 200, F and H). The number of chromosomes in each cell is *always even* and *always constant* for each member of a species, with certain exceptions to be alluded to presently, but the number varies in different species, a few examples of which follow.

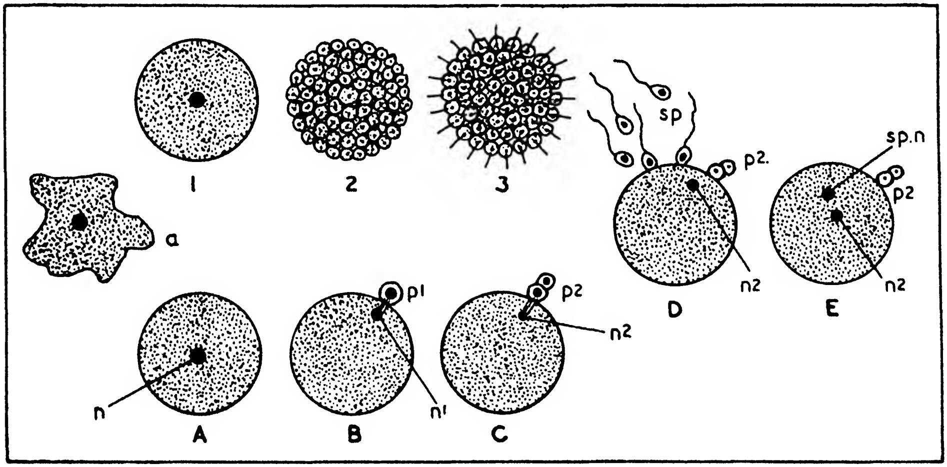



FIG. 206.—Fertilization. The diagram shows, in the upper line, the development of spermatozoa; and in the lower line the maturation and fertilization of the ovum. *a*, an amœboid sex-cell; A, ovum with germinal vesicle ($n$); B, ovum pushing out first polar body, $p^1$, and leaving nucleus, $n^1$, reduced by half; C, extrusion of second polar body, $p^2$; nucleus, $n^2$, now reduced to one-fourth of original; 1, a mother sperm-cell; 2, dividing into immature sperms; 3, dividing into mature sperms, *sp*; D, the entrance of a sperm into the ovum—note only one enters, as a rule; E, the male nucleus, *sp. n*, approaches the female nucleus, $n^2$. When these two nuclei unite, fertilization has taken place. At bottom, fertilization is a phenomenon of chemotaxis, or, as it is sometimes termed, chemotropism (Gk. *Chemos*, Chemical juice; *Taxis*, arrangement; *Trope*, turn—words covering the movement of one living organism to another one through the attraction exercised by specific chemical compounds synthesized by the one living organism upon the other, or by dead organic or other matter upon an organism). Thus an amœba will move from a comparatively great distance to an alga on which it feeds, and the fungus myxo-mycetes will migrate towards putrefying leaves or wood (positive chemotaxis) and way from a solution of common salt (negative chemotaxis). (After *Geddes* and *Thomson*.)

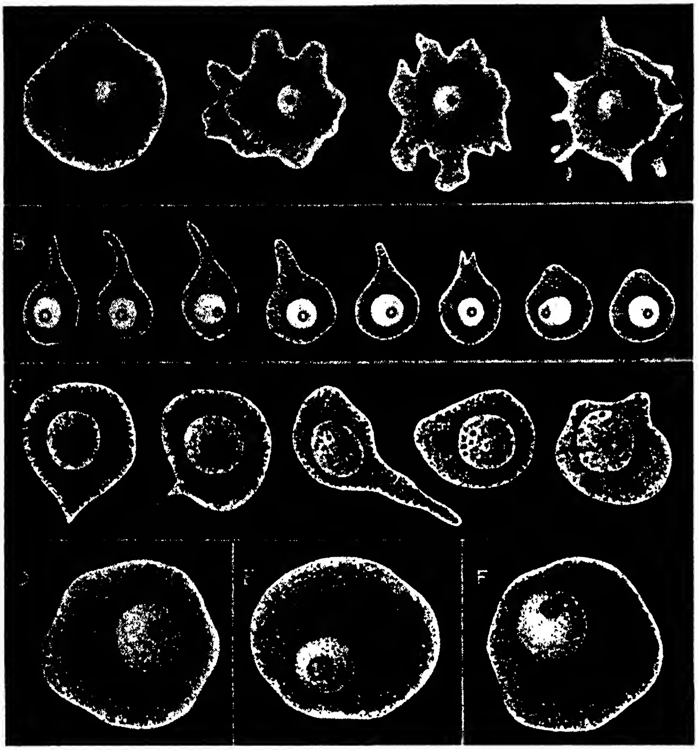


Fig. 207.—Egg-cells. A, of the sponge; B, of a hermit crab; C, of a cat; D, of a trout; E, of a hen; F, of man.

Note that the ova of fish, bird, and man are practically indistinguishable from one another.

## Reproduction and the Growth of the Sperm, Egg-Cell, Embryo, and Fœtus.

"Man becomes man only after traversing organizatory states which assimilate him first to fish, then to reptile, then to birds and mammals," says G. R. de Beer, quoting M. Serres.

Space will permit only of a brief sketch of the very complex processes that occur during reproduction and the intra-uterine events immediately succeeding it.

Among the lowest living things, an organism such as Amœba (Fig. 200), in order to beget offspring, splits into two approximately equal parts, each of which leads an independent existence very much the same as that it has itself experienced. At a slightly higher level of evolution, the separate bodies of two organisms of the same species come together, fuse, and thoroughly mix their contents, as may be seen in *Heteromita* (Fig. 202),

*Paramœcium*, and other flagellates. Subsequently the new organism so produced may, like Amœba, divide into two offspring or throw off parts of its body in the form of spores. In this process of "conjugation" we see the dawn of sex, which carries the advantage that the new single organism contains within itself living matter that combines the experiences, so to speak, of two individuals. Both these phases of Evolution are characteristic of the reproduction of single-celled, or unicellular, animals and plants. With the advent of many-celled animals, or metazoa—so called to distinguish them from the single-celled protozoa—an entirely new method of reproducing fresh individuals came into being. These metazoa include all creatures from sponges and jelly-fish to reptiles, mammals, birds, and man. Between the single-celled and many-celled animals is a sort of buffer state, combining features of each kind, represented by the colonial protozoa (volvox and proterospongia). In the general make-up of the metazoa, specialized cells are set apart for the performance of specific duties, such as digestion, sensation, locomotion, reproduction, and so forth; in other words, "division of labour" has come on the scene. Among these specialized cells are those segregated to enable the organism to reproduce itself; they are the sex-cells, or gametes, and are of two kinds: the macrogametes, or the female sex-cells, the ova, or egg-cells; and the microgametes, or male sex-cells, the sperms, or spermatozoa. In the more lowly metazoa, such as worms and snails, both kinds of gametes are housed in the same animal; but in higher metazoa they are contained in different

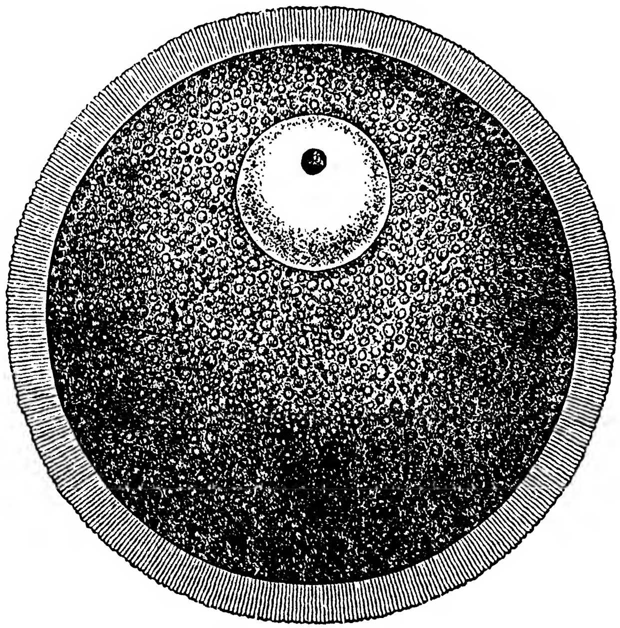
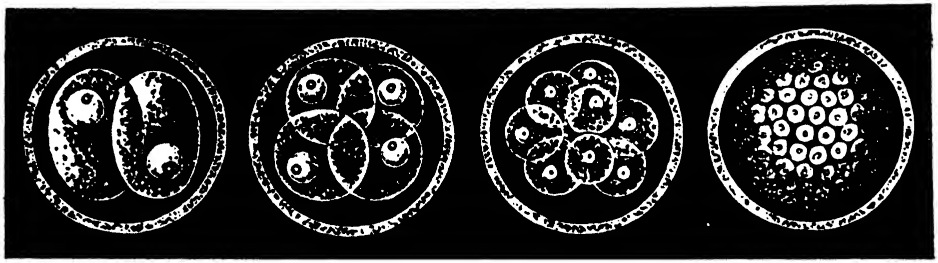


Fig. 208.—Human Ovum, or egg-cell, mature and greatly magnified. By mature is meant that it is full-grown and ready for the entrance of a spermatozoon to fertilize it. The diameter of this cell is about the 1/120 inch.



A B C D

FIG. 209.—Cleavage, or Segmentation, of the Fertilized Egg-Cell. A, B, C, 2-, 4-, 8-celled stage. D, Morula stage.

ones: the ova in the female, the spermatozoa in the male—both in that composite human being termed a hermaphrodite. These sex-cells form a very small proportion of the total cells of the body, known as the somatic cells or body-cells, which compose the brain, muscle, blood—in fact, all the bodily organs, except the sex-glands. The female sex-cells, or ova, evolve in the female in special organs called ovaries; while the male sex-cells, or spermatozoa, evolve in the male within special organs called the testes or testicles. Collectively, the two organs are termed gonads, and the two kinds of sex-cells, germ-cells or gametes. The individual evolution of the two sets of gametes is termed spermatogenesis in the case of the male, and oogenesis in that of the female; these we will now briefly consider.

## SPERMATOGENESIS.

Lying just inside the tough fibrous coat of the testes are certain large cells, the *spermatogonia*. These divide into subsequent generations of cells with well-marked nuclei, *the primary spermatocytes*. The proper complement of chromosomes—the bearers of the hereditary units, or *genes*—for each body-cell or somatic cell, as well as for each immature or unripe gamete, is, for man, 48; this somatic number is known as the *diploid* number. There now takes place in each primary spermatocyte an important process called "meiosis," a reducing division, or *reduction*, in which 24 of the 48 chromosomes are discarded, thus leaving 24 in each cell. This is the *haploid* number peculiar to each human ripe gamete, whether male or female. The number of diploid and haploid chromosomes differs in different species of animals and plants, but is constant in each member of the same species. Taking the whole of the animal and plant worlds, the

average number of diploid chromosomes per cell is 12, and of haploids 6. The diploid number is almost always even, because it must be divisible by two, to produce the haploid number. The lowest number of chromosomes recorded is two diploids and one haploid in the case of the round worm *Ascaris univaleus*; an allied species, *A. bivaleus*, has 4 diploids and 2 haploids. Among animals, protozoa boast of the largest number of chromosomes—viz., 308 diploids and 154 haploids. By a curious coincidence the plant Black Mulberry contains 308 diploids and 154 haploids. Other organisms have the following number of diploid or somatic chromosomes: certain nematoid worms 8; the mole cricket 12; a water-beetle 16; Cyclops, a water-flea, mouse, snail, lily, and Osmunda fern, each 24; pine tree and onion, 16 each; earth-worm, 32; the torpedo-fish, 36; and the shrimp, artemia, 168.

Chromosomes normal to the somatic cells and immature germ-cells are called *autosomes*, and they are responsible for the general well-being of the body as a whole; the chromosomes concerned with heredity and sex are known as the sex-chromosomes. Strictly speaking, it is not the chromosomes themselves that determine inheritance, but certain much smaller bodies, that are arranged along their length, called *genes*. Each germ-cell of the female contains two sex-chromosomes, the X-chromosomes; each germ-cell of the male likewise contains two sex-chromosomes, one an X-, the other a Y-chromosome. When a male and female gamete unite at conception to form the fertilized egg-cell, or *zygote*, the sex of the future child is decided according to the manner of the union of the chromosomes. If an X in the female gamete unites with a Y in the male gamete, the offspring will be a male; if with an X, a female.

Chromosomes vary in length from $\frac{1}{100}$th to $\frac{1}{1000000}$th inch, their average thickness being $\frac{1}{12000}$th inch. One of the largest known is the X-chromosome of *Drosophila*, the fruit-fly, which is $\frac{1}{40}$th inch from end to end.

## Reproduction, etc.

The primary spermatocyte, with its chromosomes reduced (meiosis) to twenty-four, now divides into two cells; and since, with the division of the cell as a whole, each chromosome also divides into two, one half going into each offspring cell, it follows that the two daughter-cells each contain the haploid number of twenty-four chromosomes. This reduction, or meiosis, to the haploid number present in each mature gamete is obviously a device to ensure that, when the spermatozoon and ovum conjugate, the normal, somatic, or diploid number of forty-eight chromosomes shall be restored. The first cell to be formed with the haploid number of chromo-

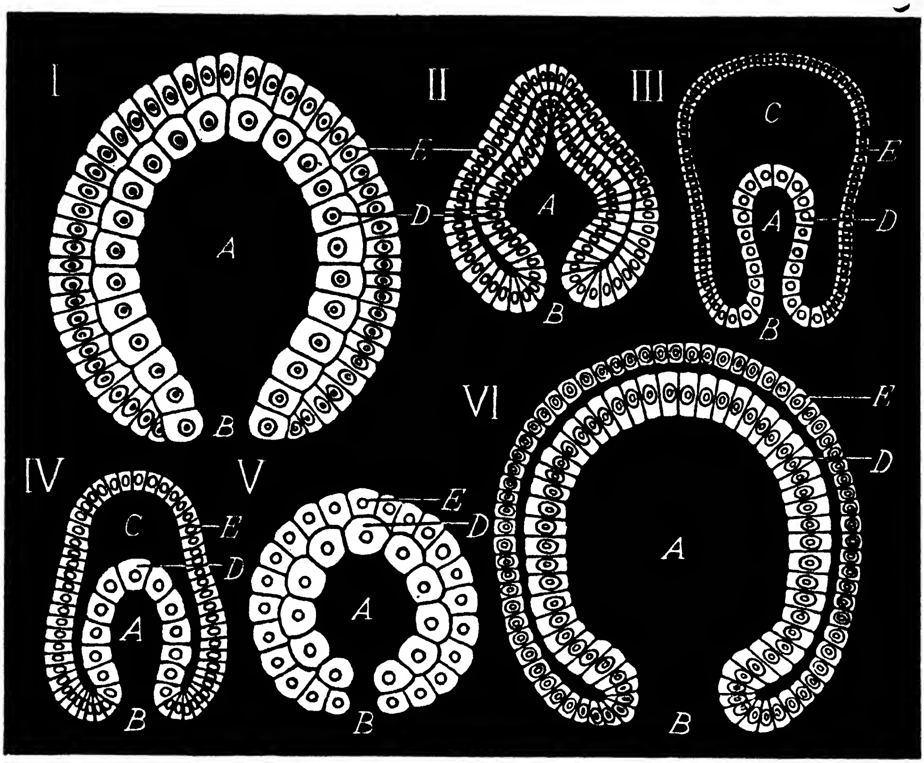



FIG. 210.—Gastrulation. I, gastrula of a zoophyte (Gastrophysema); II, of a worm (Sagitta); III, of an echinoderm (Uraster); IV, of an arthropod (Nauplius); V, of a mollusc (Linnæus); VI, of a vertebrate (Amphioxus); A, the archenteron, or intestinal cavity; B, blastopore, or primitive mouth; C, the segmentation or cleavage cavity; D, the endoderm, or intestinal layer; E, the ectoderm, or skin layer.

somes is called the *secondary spermatocyte.* In the next stage the secondary spermatocytes divide into two cells called *spermatids.* In these the nucleus of the cell, containing the twenty-four chromosomes, migrates to one end of the now very elongated cell to form the " head " of the spermatozoon. At the back of the head grows a " collar-piece," behind which is the " middle-piece." From the posterior end of this latter extends a long, wriggling tail, which, by its lashing motion, acts as a propeller or locomotor organ. When the spermatid has absorbed the last of the protoplasm of the secondary spermatocyte, and has shaken itself free of all testicular supporting cells, it has become a free *spermatozoon.* This then enters one or other of the *seminiferous tubules* of the testes, whence it is transported along a tube called the *vas deferens,* which opens into a

receptacle, the *seminal vesicle*, within which, in company with millions of other ripe spermatozoa, it is stored until such time as it is required for the fertilization of the egg-cell.

## Oogenesis.

Close beneath a layer of cells in the early developing ovary, and probably derived from them, are some large cells, the *oogonia*. Each oogonium grows, and eventually gives rise to the *primary oocyte*, which in its turn produces the *secondary oocyte*. During the development of the primary oocyte, meiotic reduction takes place, so that the secondary oocyte contains only twenty-four chromosomes, the haploid number, in lieu of the diploid number of forty-eight. It will thus be seen that in the secondary oocyte there is an almost perfect parallelism to the production of the twenty-four haploids in the secondary spermatocyte.

The actual process that culminates in the deposition of spermatozoa in the external female genital organ, or vagina, is known as sexual connection, sexual congress, coitus, or copulation, and the lodgment of the spermatozoa within the vagina is called *insemination*. In one sexual congress over 250 million sperm-cells are discharged, 125 million of which, on the average, contain Y chromosomes, and are therefore potentially male-producing; while 125 million contain the X chromosomes, and are potentially female-producing. The spermatozoa set free in the vagina swim, by means of their lashing tails, through the mouth, and thence through the *cervix*, or neck, of the uterus into the cavity of that organ. The fluids that moisten the internal surface of the uterus have a motion, caused by the lashing of the uterine cilia, that is directed from the wide top to the narrow mouth of the uterus, so that the spermatozoa find their upward progress strongly opposed. Everyone knows that a river-inhabiting fish, such as a trout or grayling, is ever swimming upstream. It does this in virtue of an automatic reflex called *positive rheotropism*, which compels an organism to swim against any current in which it finds itself; in the fish's case this is obviously to prevent itself being swept out to sea.

Like the trout, a spermatozoon is positively rheotropic, its automatic reflexes compelling it to pursue that direction in which it stands the greatest chance of meeting the ovum. The downward current of fluid on the internal surface of the uterus is, as already intimated, produced by the lashings of countless ciliated cells forming the lining membrane of the organ. The ovum, or egg-cell, expelled from the ovary, which is well outside the uterus or womb, finds itself within a closed canal called the

uterine tube, which, like the uterus itself, is also ciliated. The motion induced by the cilia is from the ovary, where the ova, or egg-cells, are formed, towards the opening of the uterine tube into the top part of the uterus. Now the ovum, in contrast with the tiny feverishly active and insurgent spermatozoon, is a relatively large and very passive organism, and would remain more or less in one spot were it not pushed along by the fixed ciliated cells of the uterine-tube and uterus, to which motive agents must also be added the muscular contractions of the walls of the tube itself. At the farther end of the tube, where it opens into the uterine cavity, the ovum is forced into one or other of the upper corners of the womb. Very soon now—and this crucial event may take place in either the uterine tube or the uterus—the ovum finds itself surrounded by spermatozoa strongly attracted to it by *chemotropism*, each struggling ardently to force an entrance into its interior. In the case of echinoderms, zoologists have watched a dozen and more spermatozoa frantically trying to force an entrance into the ovum at the same time. When, at length, one does succeed in entering, it sheds its tail, and its head—which, as we have seen, is really the nucleus of the sperm-cell—rushes towards the nucleus of the egg-cell, the impelling force again being chemotropic, and unites with it to form the fertilized nucleus; and, since both male and female nucleus contained the haploid number (twenty-four) of chromosomes, the fertilized nucleus now contains the normal, somatic or diploid number of forty-eight. The fertilized egg-cell is now known as the *zygote*. By successive divisions this gives rise to the embryo, fœtus, and new-born child, the latter having grown so rapidly that within ten months it exceeds the original ovum, in bulk and weight, more than a million million times. Following upon the entry of the spermatozoon, the egg-cell rapidly forms, and surrounds itself with a tough membrane, the *zona radiata*, which prevents the entry of more spermatozoa; at the same time it exercises a strong negative chemotropism upon all spermatozoa lying close outside it; these, now violently repelled, turn round and swim away.

Man is normally a monovulatory species; the production of more than one offspring at a birth is abnormal in his case. Twinning results in about one in ninety births. Twins are of two kinds. Identical or like twins are monozygotic—that is, two embryos are formed from a single zygote, or fertilized ovum, through the agency of a single spermatozoon. Identical twins are rare—only a quarter the number of the total twins. The second class of twins is known as dizygotic, fraternal, or unlike twins. They are due to the simultaneous liberation of two separate ova, each of which has been fertilized by a separate spermatozoon. The production of

multiple births, whether twins, triplets, or quadruplets, etc., is an atavism, and represents a reversionary process to an earlier, pre-human mammalian stage.

The next event in human oogenesis is that the fertilized ovum attaches itself to the lining membrane of the uterus. In thirty hours it has divided into two cells, and in about three days has become a sixteen-celled sphere —the *morula*, or mulberry.

From now on, in and by both mother and ovum—or, as we must at this stage call it, embryo—there is being fabricated a complex matted arrangement of tissue, together with lymph- and blood-vessels, for the purpose of supporting, nourishing, aerating, and draining away waste products of the embryo. The maternal blood is brought into very close contact with the embryo's blood, the two fluids being separated by membranes less than the thickness of a cigarette paper, so that gases, foods, and other materials in solution can readily pass from one blood to the

Fig. 211.—Pollen Cloud from Pine Trees.

The pine bears anemophilous—that is, wind-fertilized—flowers. Flowers adapted to wind-pollination are invariably small and not highly coloured; they do not produce nectar or sweet scents, both these characters being peculiar to the entomophilous, or insect-attracting, flowers. The stamens of anemophilous flowers have long filaments and pendulous anthers and produce immense quantities of very light pollen adapted for aerial transport. Correspondingly, their stigmas as a rule are large, sticky, or hairy. In the photograph the pollen cloud is so thick as to resemble the smoke of a bonfire.

other without any mixture of the two taking place. Throughout the whole ten months or so of intra-uterine life the two bloods are kept rigidly apart.

In a day in late May one may often see clouds of pollen-cells, the male ripe sperm-cells, being wafted away from the branches of conifer trees; again, over many hundreds of square yards of sea, the water may at times present a milky appearance, due to the presence of millions of sperm-cells shed by molluscs or crustaceans. Such fertilizing cells are cast haphazard into air or water, as the case may be, on the chance that currents may land some of them on virgin egg-cells. Among human beings the potential child-producing ova that mature in an average woman's life-time number a few thousand, but the potential ova-fertilizing sperm-cells that develop in the average man's life-time amount to more than a billion ($10^{12}$); about 250 million at each sexual congress are discharged, and, of these, but one normally fertilizes the egg-cell. The wastage among both kinds of sex-cells is appalling; millions of these microscopic lives are sacrificed that one may survive. In some animals the number of eggs laid appears to be directly proportional to the body-weight. G. M. King has shown that the female salmon, for instance, lays 700 eggs per year for each pound of her body-weight, so that a 20 lb. salmon lays 14,000 eggs annually. The female oyster sheds ten million eggs at one spawning, and, as she spawns six times a year, her annual produce is sixty million eggs. The haddock lays nine million eggs annually. The reproductive power of the codfish is proverbial:—

> The codfish lays a million eggs.
> The homely hen but one.
> But the codfish does not cackle
> To tell us what she's done.
> And so we prize the homely hen
> But the codfish we despise.
> Which proves to every thoughtful mind
> That it pays to advertise!

The following is a condensed diary of the career of an average human embryo within the uterus.

1st day. Spermatozoa swimming up uterine wall; ovum being pushed down uterine tube. They are mutually attracted, and a pair of them unite to form a fertilized egg-cell, or zygote, 1/120 in. diameter. Protozoa stage.

2nd day. Four-celled embryo. Metazoa stage commenced.

4th day. Embryo sixteen cells. Morula stage. Diameter, 1/17 in.

6th day. Zona pellucida present. Embryo now a blastocyst, and is well implanted in lining of uterus.

9th day. Ectoderm, primitive streak, notochordal plate, foregut and pericardial cavity, all lie between yolk-sac and amniotic cavity. Blastocyst cavity well marked. Embryo measures 0·02 in. × 0·04 in. × 0·04 in.

12th day. Blastocyst has absorbed fluid from uterine cavity, and so has considerably enlarged its dimensions.

15th day. Nourishing mesodermic villi, formed from trophoblast, have appeared. Embryo now a two-plated disc of ectoderm and endoderm lying between cavities

of amnion and yolk-sac. A cloacal membrane lies between the tail end of the primitive streak and the hinder edge of the disc. Mesodermic villi are branching. No definite human characteristics yet present. Size of blastocyst is now 0·05 in. × 0·09 in. × 0·13 in.

18th day. Cloacal membrane well established. The cloaca is a chamber formed at the posterior end of the gut; into it the rectum, or hindmost part of the bowel, the urinary and sexual ducts open. It opens to the exterior by an aperture that gives exit to waste products, and, in the female, permits of the entry of the sperm. It is a feature of certain fishes, all amphibia, reptiles, birds, and primitive mammals such as the duckbill. Head-process of notochord present. Archenteric canal beginning. Blood islands and first blood-cells and blood-vessels present in the villi and stalk of the chorion, in yolk-sac and in the embryo itself. Notochordal canal and its ventral opening present. Blastopore present. The *blastopore* is an exceedingly interesting structure from the evolutionary viewpoint. It is the sole opening into the *gastrula*, which in its turn is the evolutionary development of the *blastula*; in fact it (the blastopore) is the blastula after it has become invaginated. The blastopore originates as a primitive mouth and anus combined, since food enters the primitive gut through it, and the useless indigestible food debris leaves the gut by that same aperture. Diameter of blastocyst, 0·20 in. × 0·24 in. × 1·0 in.

20th day. Neural plate and folds have appeared; also *neurenteric canal*. In the ontogenesis of a human being the central nervous system—that is, the brain and spinal cord—is foreshadowed as a medullary groove formed out of external ectoderm layer. This groove closes up to form a tube or canal—the medullary canal in the back of the embryo. A posterior communication between this canal and the alimentary canal lying in front of it is known as the *neurenteric canal*. This is evolved out of the old blastopores, and it opens to the exterior by a small opening, the *neuropore*. In the larva of amphioxus the neuropore is an opening from the cerebral vesicle to the open sea. It represents the original aperture, in the earliest vertebrates, that led from the *central nerve canal* to the exterior. This central or neural canal opens behind into the *archenteron*, or primitive digestive cavity. Foregut is well marked. The first somite, or body-segment, has appeared. Embryonic heart now present. Blastocyst much larger, diameter 0·34 in. × 0·4 in. × 0·26 in.

22nd day. Four somites formed. Circulation of embryo, through blood-vessels of villi, has started as a result of the connecting up of blood-islands in the mesenchyme. These, by means of the connecting stalk, have linked up with intra-embryonic blood-vessels to form the beginnings of the permanent functional vascular system. The ectodermal boundaries of the neural fold have fused dorsally so as to enclose the neural tube. There are seven pairs of somites. The bucco-pharyngeal membrane, brain-plate, and left first aortic arch are present. Heart shows right and left cavities. The head and tail folds of the embryo are now prominent. The former shows, on its dorsal aspect, the neural plate that foreshadows the fore-brain. The tail-fold has carried the primitive streak and tail-bud to the hinder end of the embryo. The foregut, dorsal aorta, and *closed* neural tube, are well marked. The first pharyngeal pouch is present.

24th day. *3rd Week*. There are twelve somites. Mandibular arch is present, and below the head-fold—that is, ventral and lateral to it—is a bulge caused by the enlarging pericardium and heart. The primitive mouth, or stomatodaeum, is in evidence. Just in front of the first somite are the pre-otic sulcus and otic placode, forerunners of the ear. The first sign of the eye—the optic sulcus—has appeared. The anterior end of the primitive mouth is represented by the anterior neuropore, the posterior end by the blastopore, which is embraced by the caudal end of the neural groove, now becoming roofed over in the middle, though open in front and behind. Dorsal aorta and fore-gut prominent.

27th day. *3rd Week.* There are twenty-three somites. Primitive liver present as a simple tube leading out of intestine; another diverticulum from the food-canal higher up represents the thyroid gland. The two dorsal aortæ are in evidence and are beginning to fuse. Though there are, in all, six pharyngeal pouches present in the embryo at some time or other, these are never in appearance at the same time. At this period the first is present. The posterior neuropore, or old blastopore, persists on ventral aspect of neural groove; it is now termed, as we have seen, the "neurenteric canal." Between the endoderm and ventral, or front, aspect of the neurenteric canal lies the notochord.

30th day. *4th Week. 1st Month.* Embryo has twenty-five somites. Both are neuropores now well closed. Umbilical cord and umbilicus outlined. Third pharyngeal arch showing. Optic vesicle visible below endoderm. External ears and eyelids are in evidence. Digits present in outline on the four-limb-buds. External tail conspicuous. Length of embryo, from head to rump (base of tail), is 0·12 in. It is now definitely human-like.

34th day. *4th Week. 1st Month.* Embryo shows thirty-six somites. Tail marked. Fore and hind limbs, with rudiments of digits, present. Optic and otic vesicles represent, respectively, incipient eyes and ears, the otic vesicle sinking inwards from skin; external ears outlined. Third pharyngeal arch present. Head-tail length 0·2 in.

36th day. *5th Week. 1st Month.* Forty somites in existence. Partition between ventricles of heart has appeared. Right and left auricles and aortic arches present. Placode, foreshadowing lens of eye, present. Lower jaw is now completed.

37th day. *5th Week. 1st Month.* Length, head to tail, quarter inch. Two olfactory pits foreshadow nostrils. Otic and optic vesicles present above the primitive mouth. The cervical sinus lies behind the pharyngeal arch; sometimes this sinus, in growing, includes a piece of skin, and this may result, in later life, in a discharging branchial fistula in the neck. There are forty-four somites: four occipital, eight cervical, twelve thoracic, five lumbar, five sacral, and ten caudal. From these somites grow out the main part of the axial skeleton and muscles. At present the right and left atrium of heart are present; later these fuse to form a single atrium.

38th day. *5th Week. 1st Month.* There is an aperture in the partition between the two ventricles of heart. Peritoneal and pleural cavities are present. Primitive cardiac tube not yet completely divided into right and left halves. Wind-pipe commencing to appear. Lungs outlined as two diverticula off the primitive gut. Œsophagus, or food-pipe to stomach, demarcated. Heart now definitely four-chambered. Septum between ventricles more complete, communicating aperture between them filling up. Head-tail length, 0·32 in.

40th day. *5th Week. 1st Month.* First pharyngeal groove deepening and developing into the passage of external ear. Fore limb dividing up into arm, forearm, and hand; but hind limb still paddle-shaped. Tail beginning to retrogress. Hind-gut now present; fore-gut and mid-gut have communicated. The mid-brain is developing. Pericardium enlarging. Optic vesicles larger. An elongated opening—the *foramen ovale*—is present in partition between the two primitive auricles of the heart. This foramen has a valve which, during fœtal life, permits of aerated blood flowing from the lower *vena cava* into the left primitive auricle. Normally the foramen closes up before birth, and the two auricles remain separated and independent of one another. Sometimes the foramen persists; the blood remains venous and blue in colour, through imperfect oxidation, so that the infant has a blue complexion ("blue baby"). Head-tail length, 0·43 in.

42nd day. *6th Week. 1st Month.* A large mouth-cleft present. A bulge for the future eye has appeared. A fronto-nasal process separates the two nostrils. The eyes are now directed forwards, in the more characteristically human manner, instead of laterally. Head-tail length, 0·46 in. A definite bulge marks the liver. The heart can be seen through the transparent pericardium.

45th day. *6th Week. 1st Month.* Head growing rapidly, and vesicles of fore brain are apparent. First pharyngeal groove turning into external ear-tube. Rudiments of outer ears visible. Anterior somites beginning to disappear. Fingers well marked on hands. Paddle-like leg-bud differentiating into thigh, leg, and foot. Branchial-arch arteries getting absorbed. Septum between ventricles almost completed, and its foramen practically obliterated. Olfactory pits developing into primitive nasal cavities. Head-tail length, 0·6 in.

50th day. *7th Week. 1st Month.* Ears and eyes well marked. Eyelids forming. The pinna, or shell of external ear, has appeared and is growing around the earhole; the pinna is developed from the mandibular and hyoid arch, especially the latter. Nose conspicuous. Leucocytes and white blood-corpuscles are being manufactured. Grooves between various face structures are filling up; if these grooves persist, various facial deformities, such as hare-lip and other clefts, result. Head-tail length, 0·76 in.

56th day. *8th Week. 1st Month.* The villi of chorion, that nourish the embryo, are very profuse and surround the whole embryo and yolk-sac. Embryo completely enclosed in amnion. Gill-clefts and tail still very apparent. Hæmocytoblasts in the circulating fluids are giving origin to lymphocytes in the blood. Head-tail length, 1·16 in.

65th day. *9th Week. 2nd Month.* From now (60th day) on, the embryo is termed a "fœtus." Lymphoblasts are appearing in connective tissue around the lymph-vessels; they are provided by mesenchyme cells, or hæmocytoblasts. Overlying the optic vesicle is a thickened plate of skin called the "lens-placode," which is the scaffolding for the future lens of the eye. Erythroblasts are now very numerous, and exceed the more primitive erythrocytes. Just above the stomatodæum, or primitive mouth, the olfactory pits are deepening to form the nostrils. The fingers and toes are now separated and well defined. The cleft between the maxillary and mandibular processes is widening to form the permanent mouth. The rhombencephalon, or hind brain, is well marked. Head-tail length, 1·4 in.

70th day. *10th Week. 2nd Month.* Primitive erythroblasts disappearing. The pulmonary artery has appeared. One aorta and two *venæ cavæ* present. Right ventricle well developed. Leucocytes are being formed, inside the red marrow of the bones, for the blood and lymph, and these two fluids contain both myelocytes and white blood corpuscles.

85th day. *12th Week. 2nd Month.* Face shows definite human appearance through the further development of nose, lips, cheeks, mouth, eyelids, and ears, and the corresponding obliteration of the cervical sinus and branchial arches, as well as by the lengthening and smoothing out of the neck. Head-tail length, 2·0 in.

90th day. *12th Week. 3rd Month.* It is now possible to recognize the sex of the fœtus, by means of the external genitalia. The first rudiments of hair on the skin are present as "vibrissal hairs" that are found over the eyebrows, upper lip, wrist, and ankle regions. These vibrissæ are relics of ancient sensory or touch organs or feelers, corresponding in function to the "whiskers" of the cat-tribe, and other mammals that work chiefly in the dark. The weight of the fœtus is now 0·7 oz., the head-tail length is 2·2 in., and the head-sole length 2·8 in.

100th day. *14th Week. 3rd Month.* Vibrissæ longer and stronger, and are now present in addition on lower lip. Head-tail length, 2·8 in. Head-foot length, 3·8 in. Weight, 1·78 oz.

120th day. *17th Week. 4th Month.* Cytotrophoblast disappearing. Head of fœtus relatively very large—about one-third of whole head-tail length. Finger- and toe-nails beginning to appear as furrows on the tips of the digits. There is now an extensive crop of thin fœtal hairs, called the *lanugo*, especially present about the forehead and eyebrows; this is an atavistic hairy coat that bears no relation to the future human covering of hair. The eyes

are directed yet more ahead, and the forehead is characteristically human, being relatively high and prominent. The tail is disappearing slowly, partly by retrogression and partly by absorption into the rump. Weight of fœtus, 4·2 oz. Head-rump length, 3·9 in.; head-sole length, 5·9 in.

130th day. *18th Week. 4th Month.* Head–rump length, 4·6 in.; head–sole length, 7·0 in. Weight, 6·1 oz.

140th day. *20th Week. 4th Month.* The vibrissæ on wrists and ankles are disappearing. A few permanent true hairs cover the head just behind the forehead. Head–rump length, 5·6 in.; head–sole length, 8·5 in. Weight, 9·4 oz.

160th day. *22nd Week. 5th Month.* The membrane in the nourishing villi that separates the fœtal from the maternal blood is only 1/12,500 in. thick. The placenta is now 7·0 in. across and 1·0 in. thick. The placental membranes, composed of three layers, are 1/1000 in. thick. Head–tail length, 6·0 in.; head–sole length, 9·1 in. Weight of fœtus, 10½ oz.

180th day. *25th Week. 6th Month.* The lower limbs are still—as from their first appearance—shorter than the upper pair. The fœtus has begun to exercise its limbs, by means of spasmodic jerks within the *liquor amnii.* The mother experiences these movements as "quickening." The representative of the simian or early mammalian hairy coat, or lanugo, covers most of the body. A waxy material, "sebum," is being deposited over the whole skin by the subaceous glands; with the *vernix caseosa,* another wax-like substance, it acts as a protective and lubricant to facilitate the exit of the fœtus, or child, at birth. Head–tail length, 8·0 in.; head–sole length, 1·0 ft. Weight, 1·35 lb.

200th day. *28th Week. 6th Month.* The lanugo is becoming darker. The face is much more human-like. Head–rump length, 8·8 in.; head–sole length, 13·3 in. Weight, 2·2 lbs.

210th day. *30th Week. 7th Month.* Volume of amniotic fluid, in which fœtus is now immersed and moving about with a fair degree of freedom, is at its maximum in relation to the volume of the fœtus. Fœtus all this while, and until birth, is dwelling in an aquatic habitat; the fluid is supplied almost entirely by the mother, who forces the liquid, from her own blood and lymph, through the membranes of the amnion into its cavity. Later, however, the fœtus contributes some of the fluid in the shape of its own evacuated urine. Head–rump length, 9·48 in.; head–sole length, 14·32 in. Weight, 2·94 lb.

240th day. *34th Week. 8th Month.* Skin of fœtus plump and rounded and plentifully supplied with subcutaneous fat. Hair on head thicker and longer. The upper and lower eyelids, hitherto fused together, have now separated, and can be opened and shut. Head–rump length, 10·6 in.; head–sole length, 16·0 in. Weight, 3·7 lb.

260th day. *37th Week. 8th Month.* Lanugo, or ancestral hair, is beginning to disappear, but normal hair is longer and stronger. Finger-nails reach the finger-tips, but toe-nails are much shorter. Head–rump length, 1·0 ft.; head–sole length, 18·2 in. Weight, 5·0 lb.

270th day. *38th Week, 9th Month.* Left testis usually reaches scrotum by this date. Volume of amniotic fluid about 110 cubic inches, or 3·2 pints. Umbilical cord, 18 inches long. (The minimum recorded length for the cord is 4 inches; the maximum is 5 feet.)

280th day. *40th Week. 9th Month.* Fœtus is now "full term," and normally the child is born about this date, 280 days being a fairly usual duration for pregnancy.

300th day. *42nd Week. 10th Month.* The legs are still shorter than the arms. Circumference of head, 13·0 in. Both testes now in the scrotum. Patches of ancestral hair (lanugo) still remain over shoulder-blades. Finger-nails extend just beyond tips of fingers; toe-nails reach ends of toes. Head-rump length, 13·4 in.; head-sole length, 20 in. Weight, 7·1 lb. The child is born.

The following shows the average daily increase of weight in ounces for various animals; it may be usefully compared with that of Man: Mouse, 0·0028; Guinea-pig, 0·071; Wolf, 0·1412; Bear, 0·2471; Lion, 0·353; Man, 0·3883; Pig, 0·4942; Sheep, 0·918; Ass, 1·87; Horse, 7·06; Hippopotamus, 7·06; Camel, 14·12; Elephant, 14·12.

The following are the weights in lbs. of the young at birth; its proportional weight at birth to the weight of the mother is shown in brackets: Mouse, 0·0037 (8·5%); Guinea-pig, 0·2 (14·2%); Pig, 5·3 (3·0%); Man, 7·0 (4·0%); Sheep, 8·6 (7·8%); Cow, 77·0 (8·5%); Horse, 110 (11·0%).

The following show approximate gestation-periods in days: Opossum, 8; Mouse, 21; Rabbit, 30; Wolf, 61; Lion, 105; Lemur catta, 144; Pig, 120; Sheep, 150; Bear, 240; Chimpanzee, 260; Cow, 285; Man, 290; Horse, 340; Rhinoceros, 530; Elephant, 628.

Birds show the following variations in ozs. weight of eggs and incubation periods in days.

Weight of egg: Golden plover, 0·5; Sparrow-hawk, 0·5; Pheasant, 1·0; Hen, 2·0; Mallard duck, 2·8; Turkey, 3·2; Goose, 6·0; Kiwi, 17·0; Emu, 21; Ostrich, 54.

Incubation period: Chaffinch or canary, 13; Robin, 14; Blackbird, 15; Swallow, 15; Pigeon, 17; Sparrow-hawk, 21; Hen, 21; Pheasant, 23; Cormorant, 25; Turkey, 27; Duck, 28; Goose, 29; Buzzard, 31; Swan, 42; Cassowary, 65.

## Reproduction.

The following forty-three fœtal skulls were measured by the writer. They indicate the rate of growth of the human head before birth.

| Number of skulls measured. | Average age of fœtus; taking birth at tenth month. Months. | Antero-posterior of maximum front to back diameter of skull, Inch. | Maximum bilateral or side to side diameter of skull, Inch. | Maximum height of skull taken from top of head (vertex) to level of line joining the ear-apertures, Inch. |
|---|---|---|---|---|
| 3 | 2·83 | 0·68 | 0·54 | 0·48 |
| 3 | 4·06 | 1·30 | 1·11 | 0·80 |
| 3 | 5·26 | 1·89 | 1·68 | 1·64 |
| 3 | 5·70 | 2·34 | 1·88 | 1·70 |
| 3 | 6·60 | 2·89 | 2·25 | 1·98 |
| 4 | 7·10 | 3·39 | 2·83 | 2·23 |
| 1 | 8·10 | 4·04 | 3·40 | 2·72 |
| 4 | 9·09 | 4·29 | 3·43 | 2·79 |
| 6 | 9·23 | 4·05 | 3·35 | 2·74 |
| 13 | 10·00 | 4·18 | 3·40 | 2·78 |

The following forty-five skeletons (fœtal) were also measured by the writer. They will provide an indication of the pre-natal rate of growth.

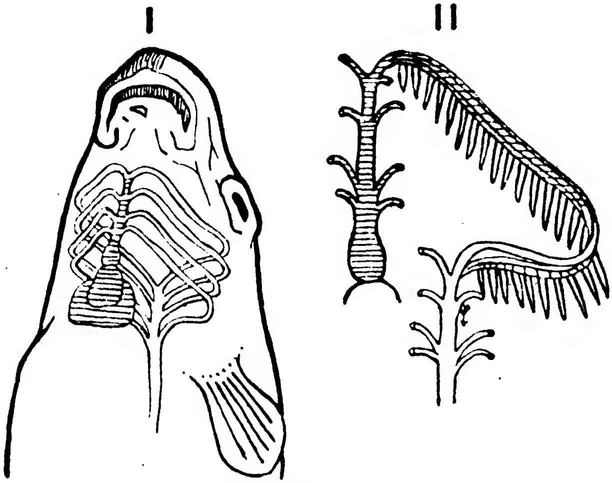
| No. of skeletons measured. | Average fœtal age. | | Average length of fœtal skeleton. |
|---|---|---|---|
| | Days. | Weeks. | |
| 4 | 67·5 | 9·0 | 1·59 |
| 4 | 87·5 | 12·0 | 3·06 |
| 4 | 106·87 | 15·0 | 4·51 |
| 4 | 127·5 | 18·0 | 5·96 |
| 4 | 147·5 | 21·0 | 7·49 |
| 4 | 167·5 | 23·0 | 8·90 |
| 4 | 187·5 | 26·0 | 10·43 |
| 4 | 207·5 | 29·0 | 11·80 |
| 4 | 227·5 | 32·0 | 13·22 |
| 4 | 247·5 | 35·0 | 14·63 |
| 4 | 267·5 | 38·0 | 16·05 |
| 1 | 280·0 | 40·0 | 16·96 |

TABLE TO INDICATE RELATIVE RATES OF PRE-NATAL GROWTH OF THE BODY, BRAIN AND SPINAL CORD.

| Age in days. | Length, head to base of tail, Inch. | Length, head to sole of foot, Inch. | Weight of brain, Ozs. | Volume of brain, Cu. inch. | Length of spinal cord, Inch. | Length of brain and spinal cord, Inch. |
|---|---|---|---|---|---|---|
| 54 | — | 1·0 | — | — | — | — |
| 105 | 3·1 | 4·0 | 0·12 | 0·007 | 0·33 | 0·75 |
| 140 | 5·3 | 8·0 | 0·57 | 0·035 | 2·8 | 3·92 |
| 180 | 8·0 | 12·0 | 1·54 | 0·11 | 4·24 | 6·24 |
| 300 | 13·4 | 20·0 | 12·98 | 21·5 | 5·8 | 9·40 |

Everyone is familiar with the general appearance of a fish's gills, but few people realize that they figure not only in our pedigree, but in our individual development, and that every cat, dog, or man, possesses their relics. Their arrangement in the fish is shown in Figs. 212 and 213. In the latter figure we see how the symmetrically disposed blood-vessels in the fish become modified in the bird and the mammal in such manner that the main blood-stream turns to the bird's *right*, but to the mammal's *left* side.

We see, further, that both in the bird and the mammal these arches begin on the original plan required for a fish, but the heart has become a far more complex organ, and most of the gill-arches have disappeared. Note that though mammals and birds have come through fish-ancestors



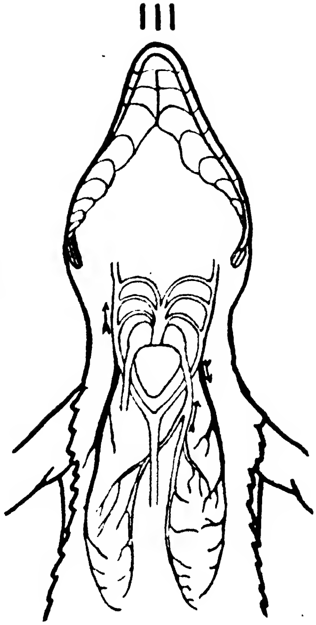




FIG. 212.—Hearts and Gill-arches. I, diagram of heart and gill-arches of a fish; II, one gill-arch with branchial fringe attached; III, heart and gill-arches in a lizard. The gill-arches are called aortic arches in air-breathing vertebrates.

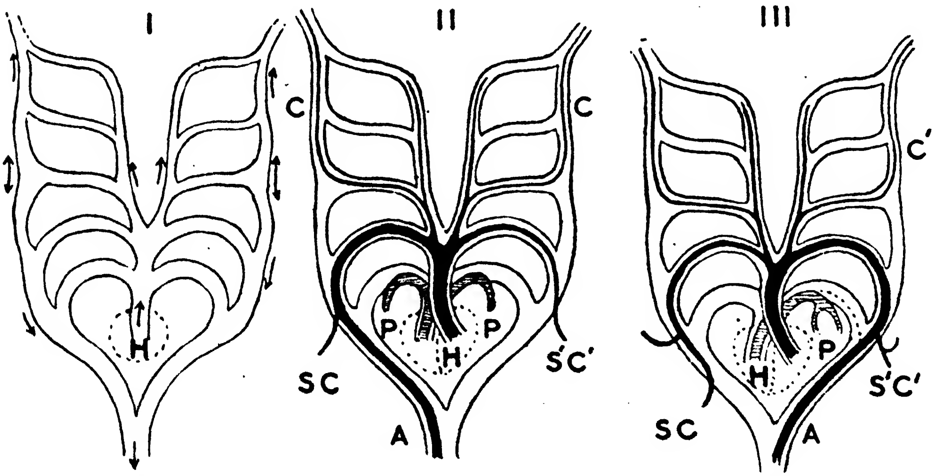



FIG. 213.—Schematic arrangement of Gill-arch blood-vessels in Fish (I), Bird (II), and Mammal (III), as seen from the front. H, heart; P, pulmonary artery; CC¹, carotoid arteries; SC, S¹C¹, subclavian arteries; A, aorta, the main artery to the trunk and lower limbs. In man the first, or mandibular, and second, or hyoid, arches atrophy. The third becomes the first part of the internal carotid artery. The fourth, on the right side, forms the subclavian artery; on the left a part of the aorta. In fish the aorta leaves the heart and curves round to the animal's right and left. In the bird the aorta curves round to the right; in man it curves to his left, and while an embryo the same arrangement exists for a time as in the fish.

with the same number and arrangement of gill-arch blood-vessels, yet the main artery in mammals is not on the same side as that in birds.

This, again, presents a question which only Evolution can answer: If mammals and birds have not come from a common ancestor, why do they begin exactly alike in this respect, only to *waste* more than half these gill-arches and adopt quite a different permanent arrangement?

## Rudiments.

Depicted in Fig. 214 are various animals in three pre-natal stages. In every instance in the top line can be seen the gill-clefts, and they are as evident in the chick and in man as in the fish. These gill-clefts carry us back several million years, before man's ancestors dwelt on the land.

**Fish. Salamander. Tortoise. Chick. Hog. Calf. Rabbit. Man.**

Fig. 214.—A Group of Embryos.

**Note the conspicuous part played by the gill-arch structures in all classes of animals above fishes. This is explained by the enormous length of time in which the ancestral line of man was aquatic and probably coincided with that of certain ancient fishes.**

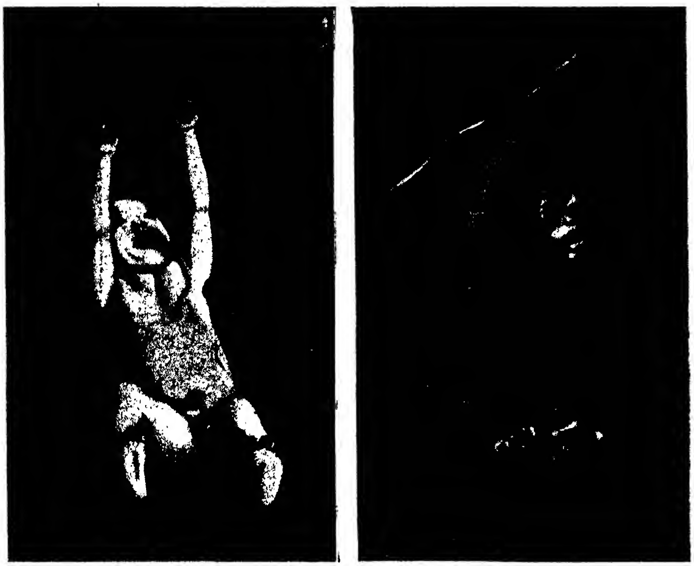


FIG. 215.—An Infant three weeks old, supporting its own weight for over two minutes. The attitude of the lower limbs, feet, and toes is strikingly ape-like, as will be seen in the picture of the young Orang-Utan.

In all animals these and many other now useless structures appear, survive for a brief time, and then either completely disappear or become modified into useful parts. In certain cases, however, a useless structure may persist, as such, throughout life. Before birth the horse passes through a stage that was permanent in the adult Miocene Hipparion, for the embryonic foal has three toes to its feet, though born normally as a one-toed animal. Sometimes, however, the two additional and now useless Miocene toes fail to disappear before birth, and then we have that curious "monstrosity," a three-toed horse. How are such utterly useless structures to be explained? "What mean the unused gill-clefts of reptiles, birds and mammals," asks Sir Arthur Thomson, "unless the ancestors of these classes were fish-like? What mean the teeth of very young whale-bone whales, of an embryonic parrot and turtle, unless they are vestiges of those which their ancestors possessed? There are similar vestigial structures among most animals. In man alone there are about seventy little things which might be termed rudimentary; his body is a museum of relics. We are familiar with unsounded or rudimentary letters in many words: we do not sound the 'o' in leopard or the 'l' in alms; but from these rudimentary letters we read the history of the words."

Not only structures, but actions may be vestigial, such as the preliminary turning round and round of a dog about to lie on the hearthrug, and the raising of the upper lip when a young lady sneers. The ancestral dog had

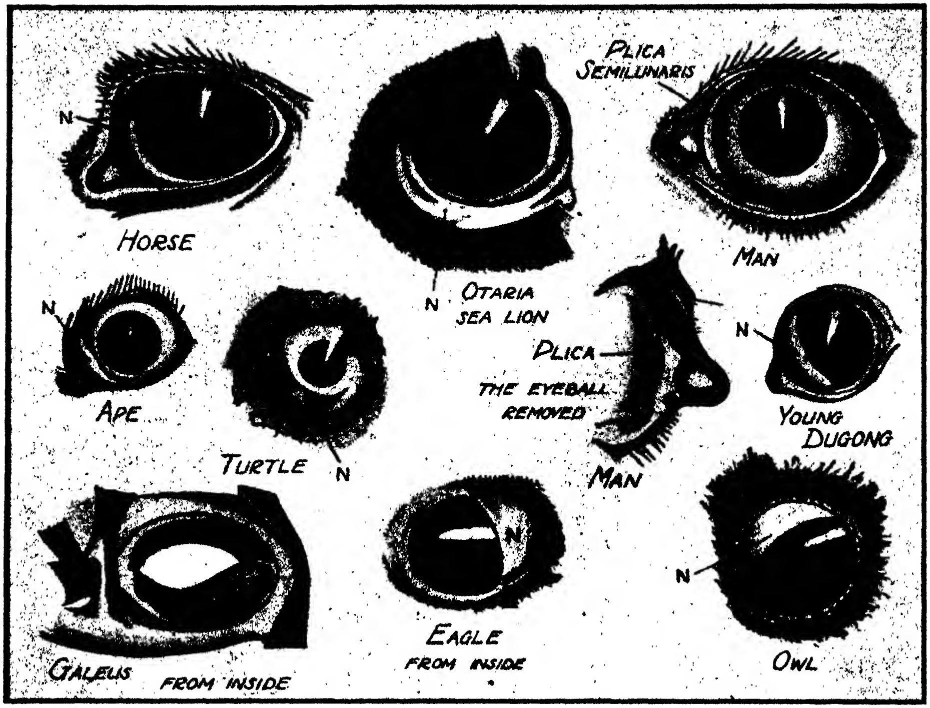



FIG. 216.—Illustrations of the Nictitating Membrane in the various animals named. The letter N indicates the membrane in each case. In man it is atrophied, and known as the *plica semilunaris.* In the case of *Galeus,* a shark, the muscular mechanism is shown. In the frog and lizard the mictitating membrane is free and readily seen. In birds it is constantly being drawn across the surface of the eyeball, and may be kept for a long time in front of it. It is a cleaning and protecting mechanism and has the advantage that, when in use, it does not rob its owner of vision. It is useless to man, its function of cleansing and protecting the eyeball having been transferred to the upper eyelids.

to make a "form" in the long grass wherein to sleep; the ancestral lady had to show canine teeth if danger threatened her or her young! We of to-day are much farther away in time from our swimming, than from our climbing, ancestors, and so it has come about that, while retaining the climbing instinct, we have lost that for swimming—so much so, indeed, that, though a baby can often hold a spoon in its toes, it is utterly helpless in the water; and even an adult man, who has not *learnt* to swim, *clutches* at the water as though it were a branch, when he falls overboard into the sea. Even strong swimmers, when reason is swamped by instinct in the last moments of exhaustion, throw up their arms and grasp frantically at imaginary branches; hence the saying: "Drowning men clutch at a straw."

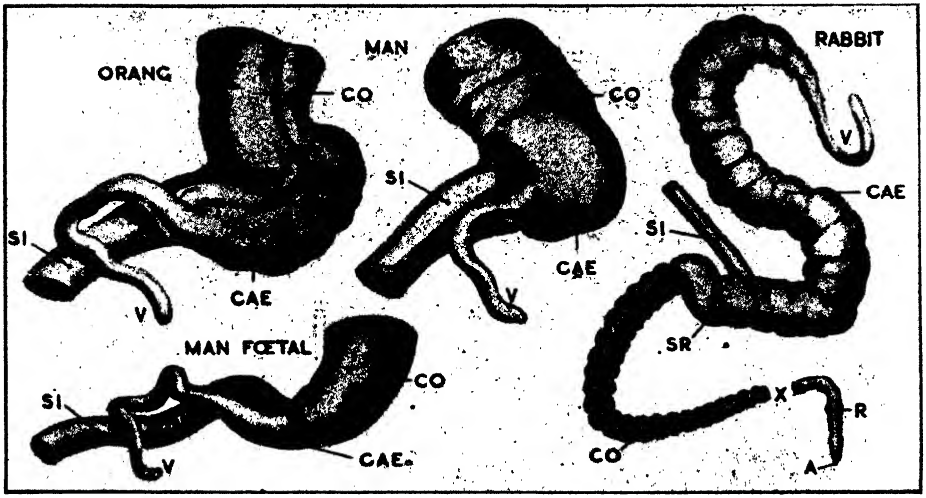



FIG. 217.—The Appendix Vermiformis (the worm-like appendix). In a lower herbivorous mammal, such as the rabbit, the vermiform appendix is of some use in digestion. In man it is worse than useless. In the rabbit the small intestine (SI) opens into a rounded chamber, the *sacculus rotundus*. This has two exits, so to speak : one leads into the big bowel, or colon, and thence to the rectum, anus, and so to the exterior; the other leads into a relatively large cæcum, which gradually tapers out to the vermiform appendix, the whole forming a *cul-de-sac*. In the rabbit, cæcum and appendix act as an accessory organ of digestion whose function is to get the last ounce of nourishment out of the vegetable material being digested. This achieved, the insoluble debris is forced back through the *sacculus rotundus* into the colon and ejected. The cæcum and appendix of the human fœtus resembles that of the rabbit much more closely than does that of the adult man. V., vermiform appendix; CO., colon; CAE., cæcum; SI., small intestine; SR, sacculus rotundus; A, anus.

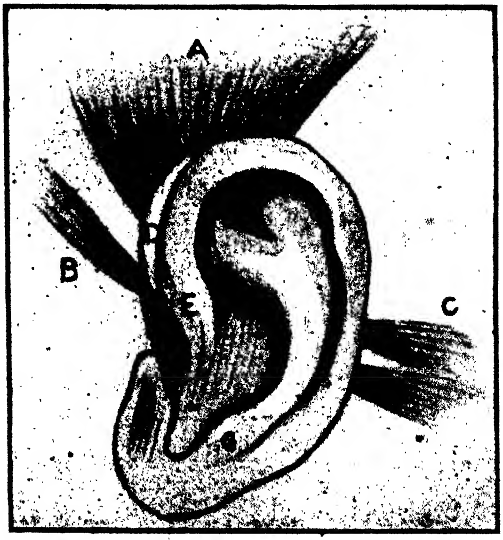



FIG. 218.—The rudimentary, or vestigial and useless, muscles of the human ear. Above is the muscle that erects the external ear, the *attollens* (A); behind are the muscles that directed it backwards, the *retrahens* (C); and in front is that which "cocked" the ear forwards, the *attrahens* (B).

The human ear is developed from the cavity and boundaries of the first branchial cleft; the cavity itself is converted into the external auditory meatus, or passage, leading to the drum. Three eminences appear on the margins of the branchial cleft, which become transformed into the various parts of the shell of the ear.

A, Attollens aurem; B, Attrahens aurem; C, Retrahens aurem; D, Helicis major; E, Helicis minor; F, Tragicus; G, Antitragicus.

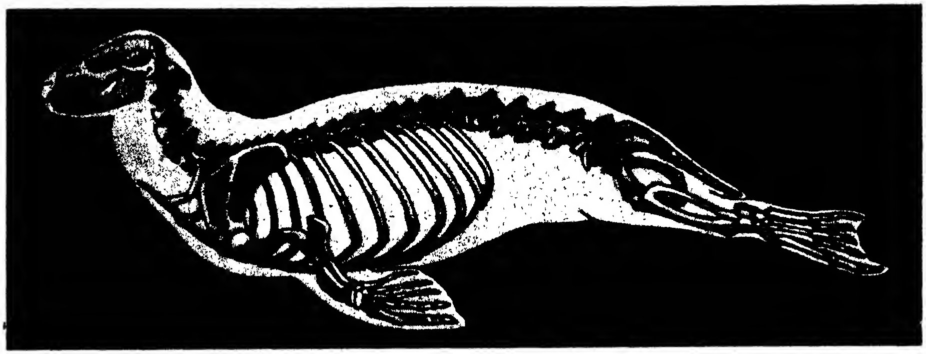


FIG. 219.—Skeleton of a Seal.

Seals are marine carnivora; very specialized swimmers, they readily catch fish, on which they feed, though they are clumsy and helpless on the shore, up which they shuffle to bring forth their young. Most of them, owing to their aquatic life, have lost their external ears. The tail is short and lies between the two extended hind-limbs. There are five webbed digits. Seals are most intelligent creatures and have a well-convoluted brain. The palms of the hands and soles of the feet are covered with hair. The testes never leave the abdomen. It is significant that the young of the arctic seal is white, but adults do not keep up this protective colouring.

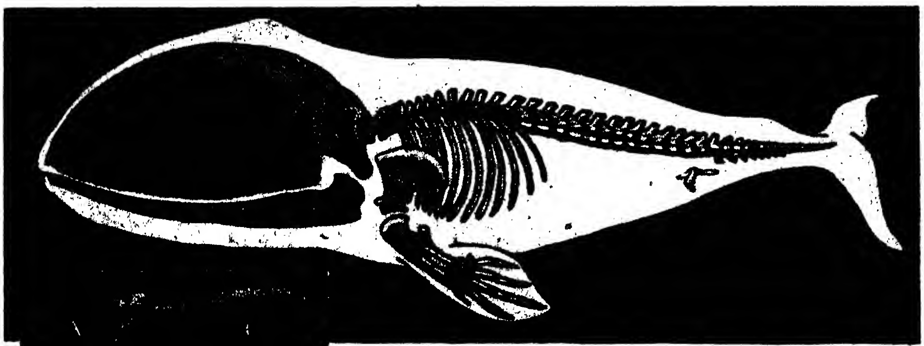


FIG. 220.—Skeleton of Greenland Whale, $\frac{1}{60}$th natural size. Rudimentary bones of the pelvis and hind-limb, magnified (inset): A, pubes; B, femur; C, ischium.

Whales are warm-blooded mammals that suckle their young. As a rule, only one is born at a birth; very rarely two. They are the largest animals on the earth at the present day. A large whale, such as the Sulphur Bottom, could permit of an African elephant standing upright inside its skeleton. The toothed whales feed on cuttle-fishes as large as beer-barrels; the whalebone whales, on minute surface-swimming animals and plants. Of all the mammals, the young of the whale are the most precocious. The front limbs are paddle-like flippers, which are used to balance and turn the animal sideways. The tail is horizontal, and is the chief organ of locomotion and for altering the animal's direction of motion upwards or downwards. The fore-limbs are 4- or 5-fingered. The hind limbs contain the rudiments of thigh- and leg-bones, as shown inset and in the hinder part of the whole animal. The testes remain intra-abdominal. As with other mammals, there are the rudiments of two sets of teeth.

FIG. 221.— A Python. A, indicates the position of the hind limbs.

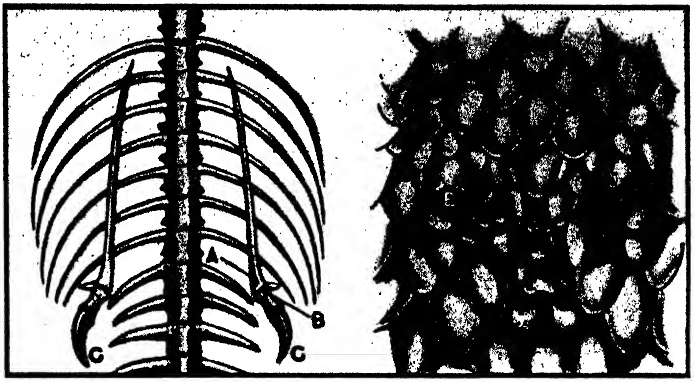



FIG. 222.—Hind limbs of the Python.

Contrary to the state of affairs in whales, the fore-limbs of snakes and serpents have completely disappeared, whereas hind-limbs, or their rudiments, tend to persist. Boa-constrictors, pythons, and a few other large snakes show distinct traces of the rudiments of a pelvic girdle, and even of a thigh-bone and nails. A, The ilium, or hip-bone; B, The femur, or thigh bone; C, Relics of digits and claws. Note toe-nail (E) peeping out between ventral scales (right).

Infants bend their feet inwards, so that the soles, in a great measure, face one another. This is still more marked in the embryo. (See "Man," bottom line, Fig. 214.) It plainly refers to a state of things among the simians, in all of whom the feet are turned inwards to help them to grasp the branches.

The clenching power of the hand *and foot* is very remarkable in the human infant for the first few weeks after birth. The young of apes give us the reason for this, since by clinging with both hands to the hair of their mother's armpits, and encircling her body with their legs, they leave all her limbs free for climbing. Dr. Louis Robinson was the first to demonstrate the extraordinary power of the human infant in clinging to a branch and so supporting its own weight for some minutes (Fig. 215). Experiments in America have shown that the negro baby only a few days old can hang on by its hands from a stick for a much longer time than the white.

Throughout the vertebrate series there occur in the inner corner of the eye the remains of a transparent eyelid called the nictitating membrane (Fig. 216). Its function in those animals where it is fully developed (one can often see fowls using it) is to sweep over the surface of the eye both to clean and to protect it. Why do the horse and man possess this

shrivelled-up relic? Because they are descended from some common set of ancestors in whom this cleansing and protective eyelid was functional, as it is to-day in the birds, tailless amphibians, some sharks, and many reptiles.

In Fig. 217 we see the organ which, when inflamed, is the source of that troublesome disease, appendicitis. The appendix is the worm-like tag attached to the big bowel just below its junction with the small one. This structure is large and useful among many herb-feeding animals, but in man it serves no such purpose, and, indeed, is a source of danger. In the orang it is bigger than in ourselves, and in the fœtus of man and ape it is relatively larger than in the adult, and much more like that of herbivorous animals.

In Fig. 218 are shown the useless muscles of our ears, relics of those that enabled our wild ancestors to move these organs so as to catch every sound, just as horses and foxes do to-day. Human beings and the higher apes have almost entirely lost this power to move their ears, though here and there an individual turns up who can do so to a slight extent.

The seal and the whale (Figs. 219, 220) are warm-blooded mammals that have come from four-legged terrestrial ancestors. In the seal we see all the bones of the hind legs shortened up and directed backwards till they form a false tail, which lies behind and below the relic of the true one. So comparatively recently—say twenty million years ago—has the seal taken to aquatic life that every baby-seal still has to receive lessons in swimming from its mother. In the whale, only the front limbs remain, externally;

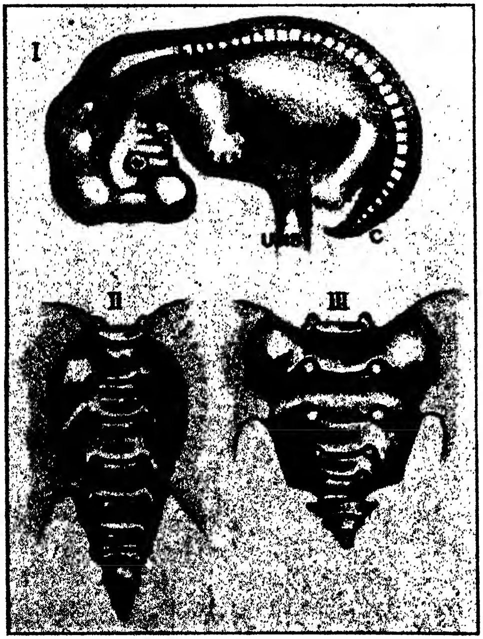



FIG. 223.—On Tails. I, outline of the human embryo, about seven weeks old, showing the relation of limbs and tail to the trunk. R, the radial; UL, the ulnar border of the hand and fore-arm; T, the tibial; and F, the fibular border of the foot and the lower leg; AU, ear; S, spinal column; UMB, umbilical cord; B, gill-slits; C, tail. II, sacrum of Gorilla, and III, of Man, each showing the rudimentary tail-bones.

but inside the animal are the remains of the limb-girdle (A) and the thigh-bone (B). In 1921 a female whale was caught off British Columbia with a pair of hind legs that projected externally from the body, near the tail, for some four feet.

FIG. 224.—A Human Embryo from the thirty-second to the thirty-fifth day—*i.e.*, about the fifth week. Enlarged about three diameters. Note the external tail.

It is almost insulting intelligence to ask which explanation is the more satisfactory: that the whale's useless hind legs and its hand fingers—so encased in fin-like sacks as to be incapable of prehension — were specially created in such a form; or that they are the natural outcome of evolutionary processes—in the case of the hind legs, of degeneration consequent on disuse; and in that of the hands, of modification consequent on the change of function.

Equally striking is the case of the python, whose useless legs are slowly rotting away, so to speak, in the depth of its belly, the little black toe-nails, peeping out from the ventral scales, being all that remain visible (Fig. 221).

Fig. 223 shows us a gill-clefted animal with webbed limbs and a tail longer than its hind legs. It is embryonic man. Not only, at this early stage, has man a tail, but he has the remains of the muscle, the *agitator caudæ*, that once moved it about from side to side, wagged it, as it is popularly said, raised and depressed it. Anthropoid apes also possess a relatively long tail before birth, but, like man, no visible tail after that event.

Could anything show more clearly that man has come from a quadrupedal, tailed ancestor? Fig. 224 shows a drawing of the human embryo in the externally-tailed condition.

# CHAPTER TEN: PEDIGREE OF MAN

IN all cases, except perhaps in a few American Fundamentalist Universities, biologists now teach that man, together with lemurs, monkeys, and apes, belongs to the Primate group. Though he belongs specifically to one group, he is related closely or remotely to every living being. Consequently, working backwards, we should seek man's origin first in some primitive mammal from which all mammals have arisen; then in some simple vertebrate who was the common ancestor of all backboned creatures; next in a primitive metazoon that gave rise to all multicellular animals; then in a primitive protozoon from which the whole animal kingdom sprang; and, finally, in some primordial form of protoplasm, some very primitive and possibly ultra-microscopic protist that formed the common starting-point of all plants and animals. Biologists are now agreed that just as at one stage in our cooling planet there occurred the evolution, by synthesis, of the chemical elements from pre-existing simple atoms and simpler subatoms, so at another and later stage there took place the further synthesis of living matter—a form of protoplasm probably far more simple and primitive than that with which we are familiar—from pre-existing inorganic colloidal solutions. This theory of the origin of life is known as *Abiogenesis*.

In lowly one-celled organisms a larger individual sometimes " swallows up " a smaller one of the same species, after which process it becomes more active and divides rapidly for a considerable period (Fig. 225). The absorbed cell has not only acted as *nutrition*, but also as a *chemical stimulus* to the larger one. Further, as it is probable that all the protoplasm of the smaller cell is not used up as food, but remains alive, " mixed up " with the protoplasm of the larger cell, there results, from the joined forces, not only a reinvigoration of the newly-formed cell as a whole, but a reaping, so to speak, of new experiences. The single cell thus

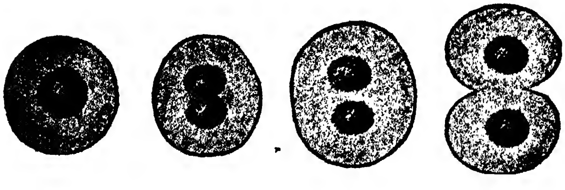


FIG. 225.—Group I.—*Chroococcus Minor*, magnified 1,500 times. The unnucleated bluish-green globule of plasm increases by simple cleavage. The central zone of each cell stains more deeply than the remainder, giving the appearance of a nucleus, but this is not the case.

resulting from the fusion of *two* now carries within itself the combined hereditary experiences of two individuals, and hence it becomes more resourceful in reacting to its environment. Such, undoubtedly, is the origin and function of sex-union.

The Amœba (Fig. 226) recognizes the difference between a particle

FIG. 226.—Group II.—An Amœba in an active food-hunting state (highly magnified). The whole organism is simply a naked cell, and moves about by means of the variable processes that it thrusts out and withdraws into its protoplasmic body. There is a clear, round nucleus in the middle of it.

FIG. 227.—Group II.—The Ovum of a Calcareous Sponge (*Calcolynthus*). The ovum creeps about in the body of the sponge, by the same means as the Amœba. This helps us to see how the ovum of the higher animals may have come from an ancient ancestral form, like the common Amœba.

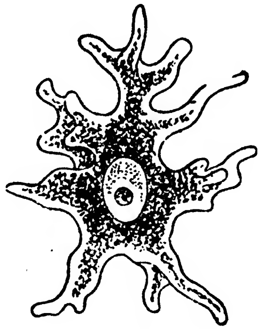


FIG. 226.

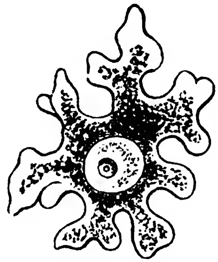


FIG. 227.

of food and a particle of sand by chemical attractions and repulsions, a property in all protoplasm known as "irritability." Such "attractions" are somewhat ponderously termed "*positive*" *chemotaxis* (or *chemotropism*), while the repulsions are known as "*negative*" *chemotaxis* (or *chemotropism*). The *cell-fission*, that forms one aspect of reproduction, is, at bottom, discontinuous growth; the *cell-fusion*, that constitutes the other aspect, is essentially a chemotactic process. The unfertilized ovum is positively chemotactic, the fertilized ovum negatively chemotactic, to all male gametes. The basis of the emotions of love and hate is biochemical!

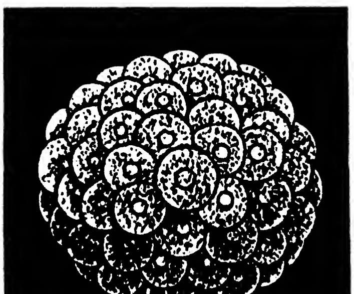


FIG. 228.—Group III.—A common example of a Moræad; the morula, or mulberry-shaped embryo. It is really a colony of Protozoa, and there are many plants and animals in this form which never advance any further. At one stage of man's embryonic life he has this appearance.

Another great stage in growth occurred when the cells, after dividing, did not separate, but clung together in a somewhat loose fashion to form colonies. This was the grand step to the formation of a "body"; it was the dawn of co-operation and division of labour. All the intelligence and beauty and triumph of the human race owe their origin to this step.

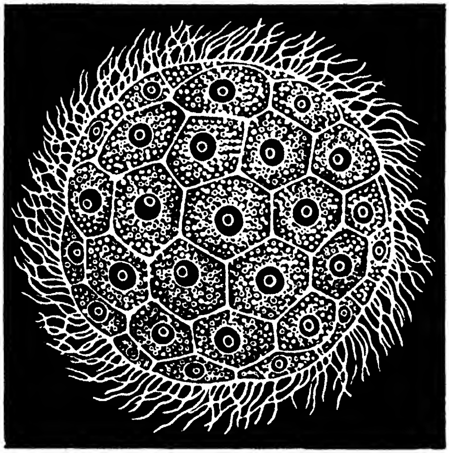


FIG. 229.—Group IV.—The Norwegian *Megasphæra planula*, swimming about by means of the lashes, or cilia, at its surface.

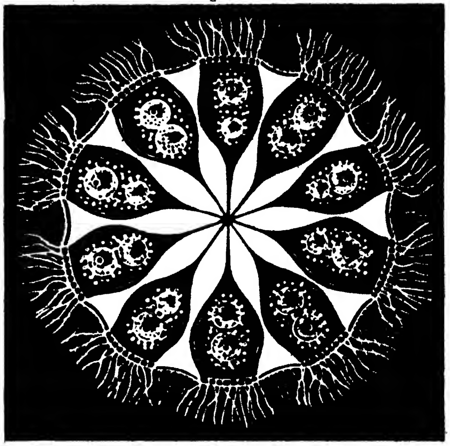


FIG. 230.—Group IV.—Section of Fig. 229, showing how the pear-shaped cells in the centre of the gelatinous ball are connected by a fibrous process. Each cell has a contractile vesicle as well as a nucleus.

Yet another important step in the upward climb of Evolution was the acquisition of a hollow body—it gave us our food-canal.

The acquirement of special apparatus in the shape of a nervous system that enabled the organism to be in constant and quick communication with the outer world added almost infinite power to the animal race. At first the skin had to play the rôle of nervous system, because it was the chief connecting medium or link between the ani-

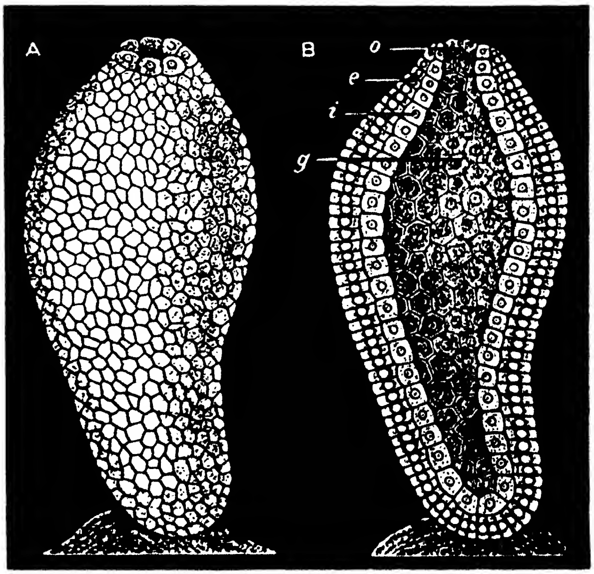



FIG. 231.—Group V.—A Gastrula Form, the ascula of Gastrophysema, attached to the floor of the sea. A, the external view; B, a longitudinal section; *g*, primitive gut; *o*, primitive mouth; *i*, visceral layer; *e*, cutaneous layer. See also Figs. 84, (p. 85), 157 (4, 8), and 210.

mal and its environment. From this simple beginning there developed, through division of labour in the cell-colony, the elaborate nervous system of the higher animals, giving them their greater intelligence.

After many millions of years the " back" of certain worm-like creatures (Fig. 236) became stiffened by the presence of a gristly rod, the notochord, which was to prove the scaffolding, as it were, for the true backbone of the fish. In this way vertebrates came on the scene.

Very gradually the aquatic vertebrate became the terrestrial vertebrate through fins becoming legs, air-bladders being turned into lungs, and gills into various other structures more adapted to life ashore. We can to-day glimpse how such transitional stages from water to land occurred by observing sea and land crabs, the double-breathing fishes, the tadpole and frog, and the water-to-land life of many insects such as mayflies and dragonflies.

At long last the purely terrestrial quadruped took to climbing trees, and this arboreal life led to specialization of fore-feet into grasping hands. But the specialization of fore limbs in the one direction led to specialization of hind limbs in another, viz. entire support of the body. Thus, later on, was brought about the erect gait, with its enormous advantage of being able to see well around one without climbing trees. So man-in-the-making forsook arboreal life, came out into the open, and, thanks to his freed hands, became a tool-making animal and, finally, the builder of houses, cities, railways, ships, aeroplanes, and wireless.

We must remember that: (1) no one pretends to know the exact ancestor of this or that race of men; (2) man evolved through various groups of animals; (3) in no case are *living* groups the ancestors of man.

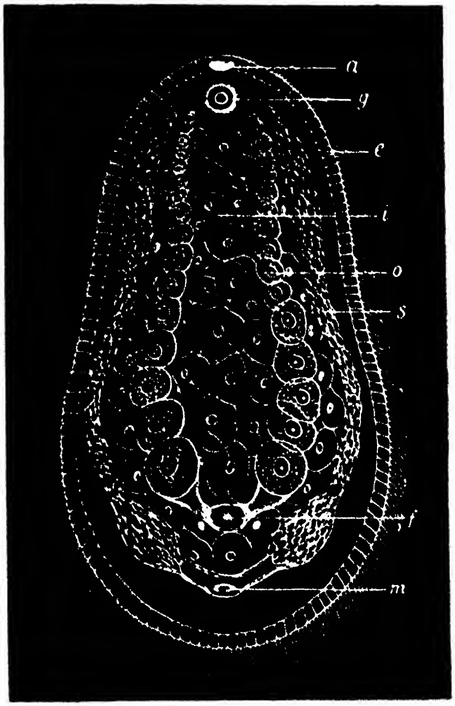



FIG. 232.—Group VI.—One of the Platodaria, *Aphanostomum Langii*. *a*, Mouth; *g*, auditory vesicle; *e*, ectoderm; *i*, entoderm; *o*, ovaries; *s*, spermaries; *f*, female aperture; *m*, male aperture.

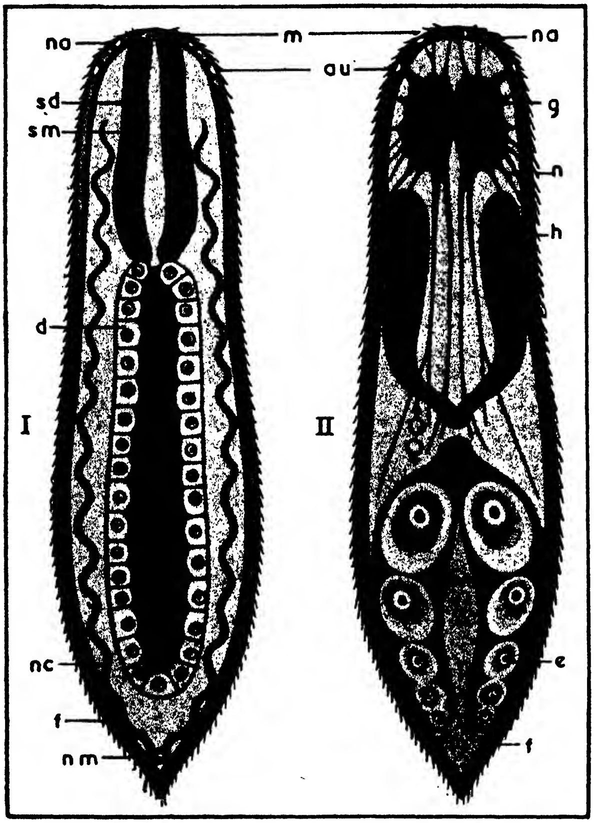



FIG. 233.—Group VI.—I, One of the Turbellaria, a simple coiled-worm (*Rhabdocœlum*). *m*, Mouth; *sd*, gullet epithelium; *sm*, gullet muscles; *d*, layer of cells lining the gastric duct; *nc*, renal canals; *nm*, renal aperture; *au*, eye; *na*, olfactory pit. II, The same, showing the other organs. *g*, ganglion representing brain; *au*, eye; *na*, olfactory pit; *n*, nerves; *h*, testicles; ♂, male aperture; ♀, female aperture; *e*, ovary; *f*, ciliated epiderm. Despite the relative complexity of these animals, if cut up into several small pieces each will grow into a perfect individual; such is their regenerative capacity.

The Amphioxus, or Lancelet (Figs. 236 and 238), is of the utmost interest as showing how vertebrates may have arisen from invertebrates. The remote vertebrate ancestor was probably a sand-burrowing and free-swimming sea-worm of the Balanoglossus (Fig. 235) type. Burrowing necessitated a certain amount of rigidity, and so the stiffening notochord was evolved. Swimming necessitated rapid movement through water and maintenance of correct orientation, so primitive fin-folds came on the scene. We can see such beginnings to-day in larval Ascidians and Appendicularia (Figs. 236 and 237). It was not long, geologically speaking, before descendants exploited these structures, the gristly rod was used as a scaffolding on which to erect, first, the cartilaginous backbone of primitive fishes (Fig. 241), and finally the bony vertebræ of the true fishes and land-vertebrates, while the primitive fin-fold became divided first into fins and later into limbs.

All existing Primates, from lemur to man, are to be regarded as the terminals—the leaves—of branches that have successively diverged from the mammalian stem since Eocene times. Most remarkable evidence of the relationship binding together all members of the animal kingdom is given by certain blood reactions. It has long been known that, if the blood cells of one animal be injected into the blood-stream of another, they are sooner or later destroyed by certain chemicals called *cytolysins* (cell-dissolvers). The rapidity of this destruction varies according to the closeness or remoteness of blood-relationship, being slow where the species of the two animals concerned is identical, rapid where they are widely different. The blood cells of a human being, injected, say, into the blood of a dog, are killed very quickly; if into the blood of a lower monkey, they are killed less quickly; if into the blood of an anthropoid ape, the destruction of the cells takes place so slowly that the net result is practically the same as when the blood of two human beings is mixed together. This curious behaviour is owing to the fact that the blood of any one species

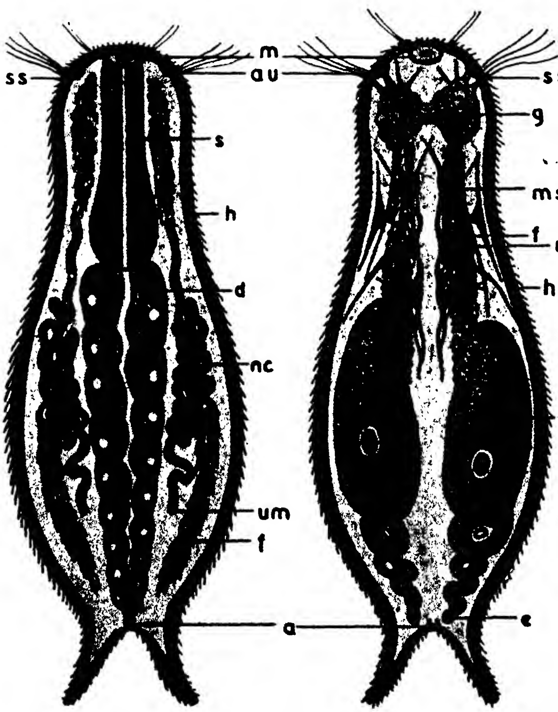



Fig. 234.—Group VII.—Two views of the *Chætonotus*, a rudimentary vermalian of the group Gastrotricha. *m*, Mouth; *s*, gullet, the fore part of which is often protrusible; *d*, gut; *a*, anus; *g*, double ganglion representing right and left brains; *n*, nerves; *ss*, sensory hairs; *au*, eye; *ms*, muscular cells; *h*, skin; *f*, ciliated bands of the ventral surface; *nc*, primitive kidneys, or nephridia; *nm*, their excretory aperture; *c*, ovaries; *e*, ova, ready for discharge.

differs markedly in chemical composition from that of all other species, while the blood of a member of any one species is almost, *but not quite*, identical in chemical composition with the blood of another member of that species. *The degree of difference of the blood of animals is directly connected with the degree of relationship between them.* Professor Nuttall, of Cambridge, has devised an exquisitely sensitive test whereby this degree of difference between two bloods, and consequently the proximity or remoteness of the two animals concerned, can be measured with great accuracy. Clear, colourless serum from human blood is injected at intervals into a vein of a rabbit. After some days this rabbit's blood will be found to have acquired remarkable properties. If a drop or two of its clear serum be added to human serum a heavy white precipitate is formed almost

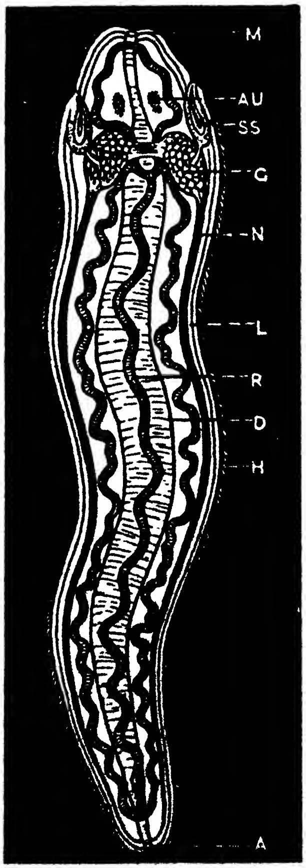
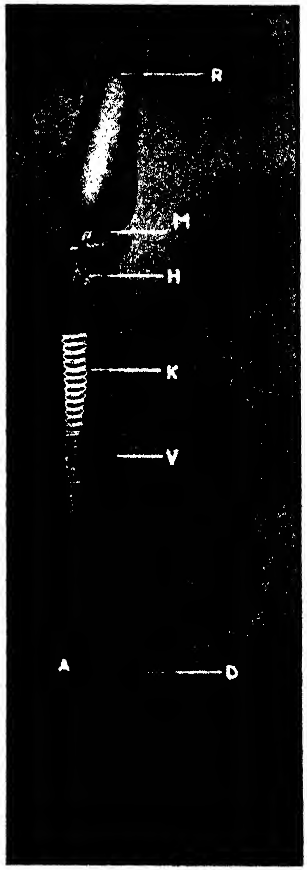



FIG. 235.—Group VII, shows two examples of Snout-worms. (Left) A simple Nemertine. M, Mouth; D, gut; A, anus; G, double ganglion, or brain; N, nerves connected to brain; H, ciliary coat; SS, sensory pits (head-clefts); AU, eyes; R, dorsal vessel; L, lateral vessels. (Right) A young Enteropneust (Balanoglossus, acorn-worm). R, acorn-shaped snout, or proboscis; H, neck; K, gill-clefts and gill-arches of the fore-gut in long rows on each side; D, digestive hind-gut, filling the greater part of the body-cavity; V, intestinal vein or ventral vessel, lying between the parallel folds of the skin; A, anus; M, mouth. Dorsally, from the fore part of the gut, a gristle-like rod grows forward into the proboscis, forming a stiffening and supporting rod. It may represent the true notochord of the vertebrates, but, since it lies ventral to the main blood-vessel and not behind it, it is more probably an analogue of the notochord.



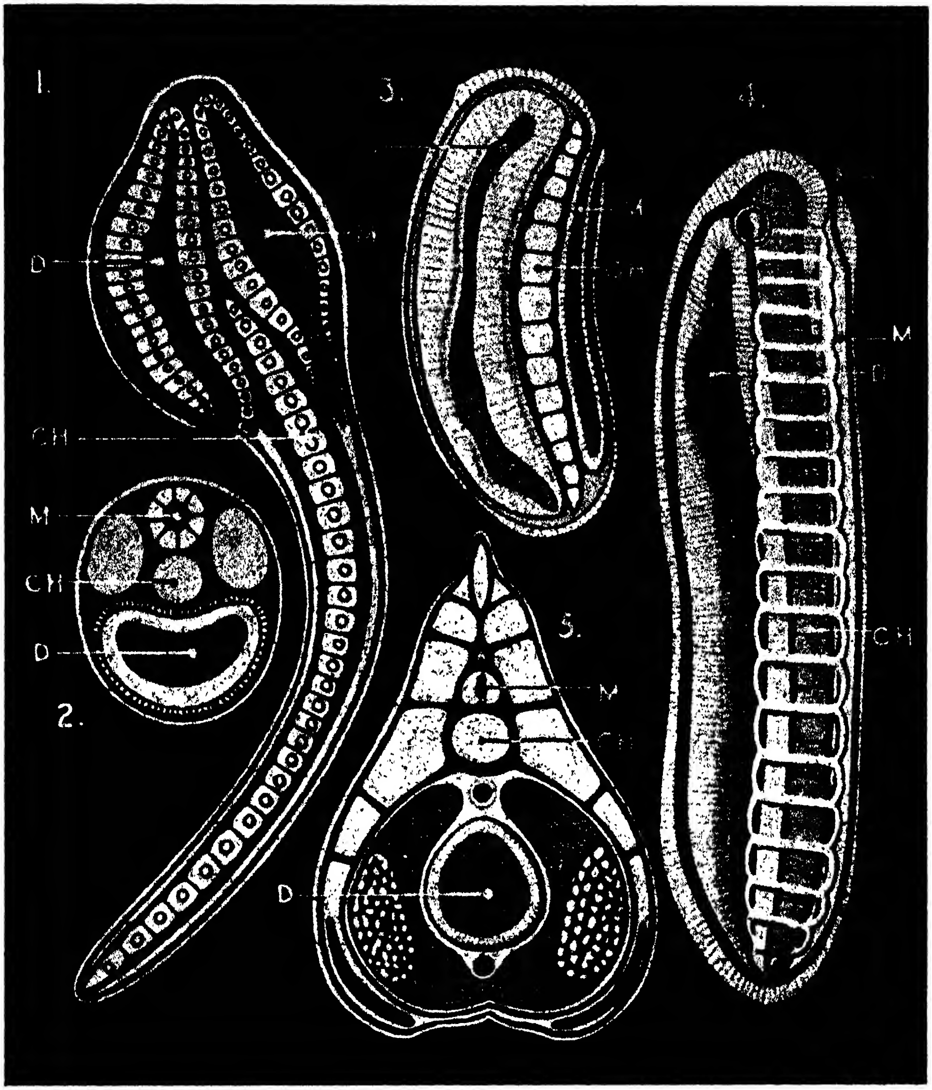



FIG. 236.—Group VIII.—Larvæ of the Ascidian and of the Amphioxus show some striking likenesses, which are of great importance, as the Amphioxus is so clear a link in the history of Vertebrates. 1. The free larva of the Ascidian. Between the medullary tube (M) and the alimentary canal (D) the chorda (CH) passes and goes the whole length of the tail to the tip. 2 is a transverse section of 1. The section is just the same as that of the Amphioxus larva (3 and 4). 3. Young larva of the Amphioxus; M, D, and CH, as in 1. 4. An older larva of the Amphioxus, with letters meaning the same; MA is the opening of the medullary tube at its anterior end. See also Fig. 238.

immediately. Practically the same result ensues if, instead of human, anthropoid ape serum is used. If added to the serum of a lower monkey or lemur, a precipitate is also formed, but more slowly and less abundantly. The amount and rapidity of formation of the precipitate decreases steadily as we descend the Primate and mammal scale. Such blood-test, apart from its more practical utility in criminology and law—for it has already been made legal use of to throw light on human relationships—has proved that:

1. Man is definitely related to all mammals, and very closely to the higher Primates.
2. The Carnivora are more closely related to one another than to the Herbivora.
3. Whales are closely related to, and have therefore almost certainly descended from, mammals of the pig type.
4. Limulus, the King Crab, is not, as many zoologists had claimed, a true crab, but is more akin to members of the spider and scorpion groups.
5. Birds are very closely connected with the reptiles. The aphorism, "Birds are but glorified reptiles," is thus confirmed.

We will now pass in review a number of groups showing the probable pedigree of man from the dawn of life.

### Group I

Group I contains only Monera, from the lowest level of the plant world. They are among the simplest organisms known to us, being mere particles of plasm or protoplasm, with little organic structure (Fig. 225, p. 224).

### Group II.—Amœbæ

The Amœba stage marks a distinct advance in cell-structure, the nucleus and cell-body being now well defined. Remember that the young unfertilized human ovum looks and behaves like an Amœba (Fig. 226, p. 225). The ovum of a sponge (Fig. 227) or of a human being (F, Fig. 207, p. 200) is phylogenetically in Group II.

### Group III.—Moræads

Here we attain a stage where separate cells have clustered together to form a multicellular colony shaped somewhat like a solid ball, such as

may be seen in various Moræad types (Fig. 228, p. 225).

## Group IV.—Blastæads

In this stage the solid ball of cells, or Morula, becomes a hollow sphere, the Blastæad or Blastula, the wall of which is composed of a layer of single cells called the Blastoderm (Figs. 229 and 230, p. 226; see also Fig. 157 [3, 7] p. 162).

## Group V.—Gastræads

Presently one part of the single cell layer constituting the Blastoderm falls in upon the other part to form a two-cell layer known as the Gastræad (Fig. 231, p. 226).

## Group VI.—Platodes

In this and the next group we pass through our worm-like ancestors. From the bilateral Gastræads arose, in all probability, the Platode worms (Fig. 232, p. 227), and, from these, Turbellarian worms (Fig. 233, p. 228). The Parasitic worms, being hopeless degenerates, need not concern us in our study of *upward* evolution. But the Turbellaria are of especial interest from the light they throw on the evolution of the alimentary canal, for they exhibit the bowel in its first and most primitive form of a straight narrow tube; hence another name of these creatures is "straight-guts," all higher animals being "crooked guts."

## Group VII.—Vermalia

Coming to the worms proper, or *Vermes*, we pass over the *Gastrotricha* (Fig. 234, p. 229) to the snout-worms, or rhynchocœla

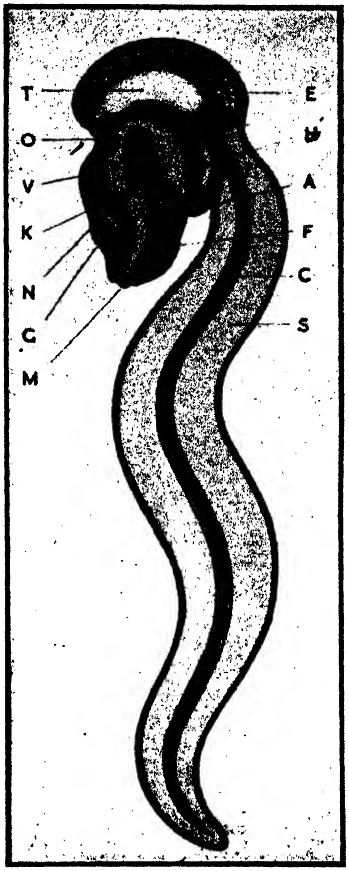



Fig. 237.—Group VIII.—An Appendicularia (*Copelata*), seen from the left. M, Mouth; K, branchial gut; O, œsophagus; V, stomach; A, anus; N, brain (ganglion above the gullet); G, auditory vesicle; F, ciliated groove under the gills; H, heart; T, testicles; E, ovary; C, chorda; S, tail. The representative of the notochord can be seen extending the whole length of the body. This supporting, stiffening, gristle-like rod, the notochord, is invariably present at some stage during the growth of the embryos of all vertebrate animals. It is of immense evolutionary significance.

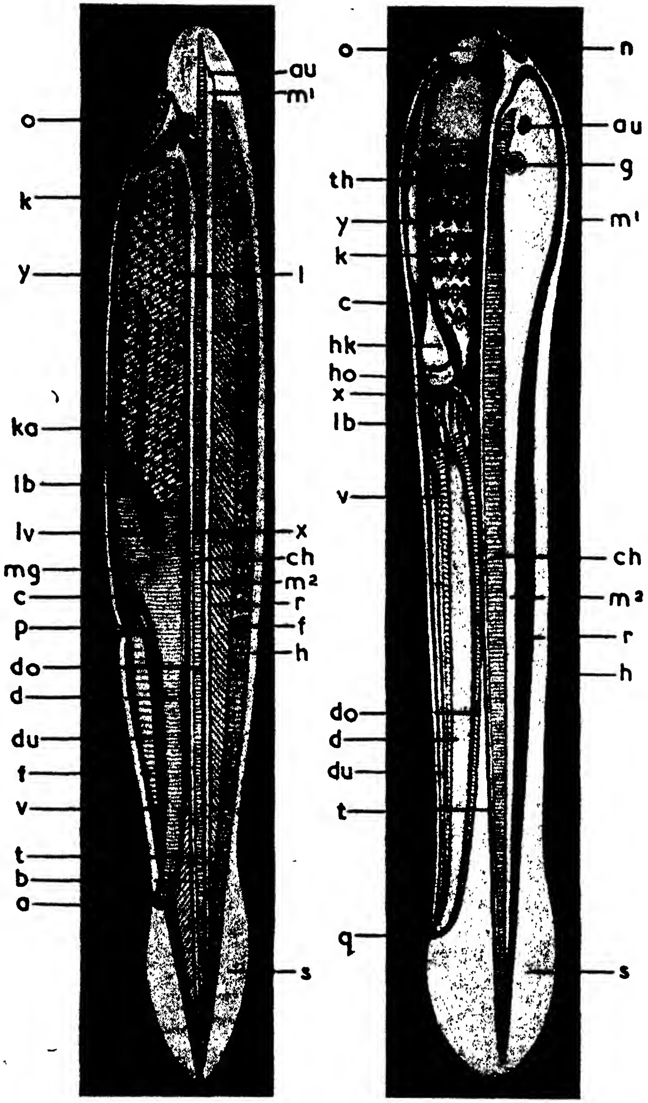



FIG. 238.—Group IX.—Adult Amphioxus (left) (× 4), Larva Lamprey (right) (× 45).—*Au*, eye; *a*, anus; *b*, ventral muscles; *c*, (upper) mantle cavity; (lower) cloaca; *ch*, chorda; *d*, alimentary canal (gut); *do*, dorsal wall of gut; *du*, ventral wall of gut; *f*, fin border; *g*, auditory vesicle; *h*, horny plate; *hk*, ventricle of heart; *ho*, auricle of heart; *k*, gills; *ka*, branchial artery; *l*, corium (cutis); *lb*, liver; *lv*, hepatic vein; $m^1$, cerebral vesicle; $m^2$, spinal marrow; *mg*, stomach; *n*, nose; *o*, mouth; *p*, ventral pore; *q*, ejection opening (cloaca); *r*, dorsal muscles; *s*, tail fin; *t*, aorta; *th*, thyroid gland; *x*, limit of branchial gut and hepatic gut; *y*, gullet groove. Amphioxus, *Branchiostorma*, or the lancelet, is of the greatest interest to evolutionists. Sir J. Arthur Thomson has described it as the "somewhat degenerate pioneer" of vertebrates, and the "far off prophecy" of fishes. It is a negative sort of creature, destitute of limbs, skull, jaws, true brain, eyes, heart, and spleen. It is about two inches long. There is a dorsal fin, tail fin, and a short ventral fin. There are no bones, and the supporting mechanism is represented by a notochord which runs from end to end of the creature.

(Fig. 235, p. 230). Balanoglossus, the acorn-worm, is probably a survivor of the ancient gut-breathing Vermes (Enteropneusts), from which the vertebrates ultimately took origin. There is a close connection between Balanoglossus and Appendicularia (Fig. 237), and both these are nearly related to Amphioxus (Figs. 236 and 238). All three organisms are of

immense value in throwing light upon the evolution of the Chordates from the pro-Chordonia; they are the original ancestors, the "Adams and Eves," so to speak, of vertebrates.

### Group VIII.—Pro-Chordonia

To wrest the secrets of Evolution from the "before-the-Chordate" animals, the Ascidians or Tunicates, we must study them in their *larval* state (Fig. 236, p. 231), for the adult is so degenerate that it has lost most of the higher or vertebrate-like features of its youth. Some Ascidians, however, such as the *Copelata* (Fig. 237), retain throughout life the *notochord* and *nerve-cord* that are the equivalents respectively of the backbone and spinal cord of higher vertebrates. There is a striking similarity between Amphioxus and the larval Ascidian (Fig. 236) on the one hand, and the larval lamprey on the other (Fig. 238).

### Group IX.—Acrania

The Amphioxus represents the lowest (*Acrania*, headless) division of the vertebrates. In Fig. 238 it is compared with a young lamprey larva. The chief characteristics which distinguish the vertebrates, or Craniata, from the invertebrates are (1) a dorsal medullary tube; (2) a notochord between this and the gut; (3) the division of the latter into branchial and hepatic gut; and (4) the internal segmentation of metamerism.

The Amphioxus is the only surviving member of the old acraniate division that arose from the more primitive pro-Chordata. All other vertebrates belong to the Craniata—skull-animals—direct descendants of the Acrania.

### Group X.—Lampreys

The lampreys (Fig. 238) fill a gap between Amphioxus and the true fishes. All the skull-animals are divided into Cyclostoma (round-mouthed), of which very few have survived (the lamprey being one), and Gnathostoma (jaw-mouthed).

Lampreys possess no bony skeleton and only a very rudimentary skull. The "backbone" of this creature (and its cousin the hagfish) *is* the notochord. Another significant point is that these animals have pairs of small cartilaginous plates arranged along the notochord on either side of the nerve-cord, thus foreshadowing the neural arches of the higher vertebrates. The brain, at first a mere bulge of the forward end of this nerve-cord, or "spinal marrow," develops later into the five cerebral

vesicles characteristic of higher vertebrates. The larva of the lamprey is popularly known as " nine eyes," in mistaken reference to the branchial apertures, for the animal is blind, what eyes there are being rudimentary and buried.

### Group XI.—Sharks

The Selachii, or sharks (Fig. 239), possess many primitive features, among which is a cartilaginous skeleton.

### Group XII.—Crossopterygian Fishes, or Fossil Ganoids

From the primitive fishes were developed the Ganoids (plated fishes), abundant as fossils. Some of these Ganoids are like sharks; others approach the Dipneusts (Fig. 240).

### Group XIII.—Dipneust (Double-breathing) Fish

These double-breathing fish constitute the link between the former and the succeeding group—in short, they bridge the gap between water-breathers and air-breathers, between aquatic and land animals (Fig. 241).

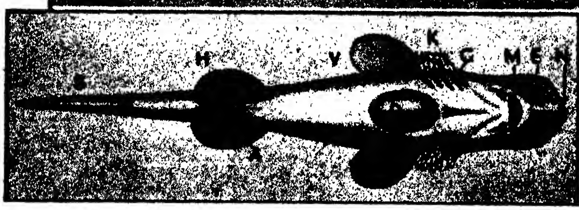


Fig. 239.—Group XI.—The lower figure shows the under side of an embryo shark. V, Breast fins; C, five pairs of gill-clefts; H, belly-fins; A, anus; S, tail-fin; K, external gill-tuft; D, yolk-sac (removed for the most part); E, eye; N, nose; M, mouth-cleft. The one above is a man-eating shark (left-side view): R¹, R², first and second dorsal fins; S, tail-fin; A¹, anal fin; V, breast-fins; H, belly-fins. The sharks are the lowest of Elasmobranch fish; they possess no air-bladder.

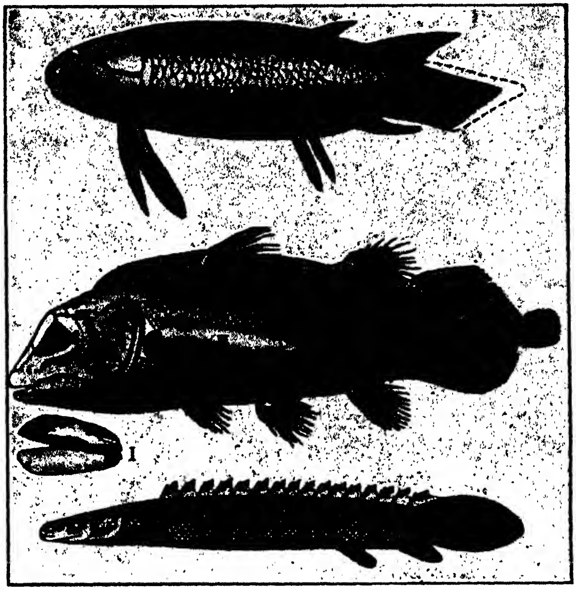



FIG. 240.—Group XII. —The top one is a Devonian Crossopterygius. The middle one is a Jurassic Crossopterygius. I, Jugular plates; II, swim bladder. The bottom one is a living Crossopterygius—the Polypterus. In polypterus the air-bladder is double, and well supplied with blood; its function is both hydrostatic and respiratory.

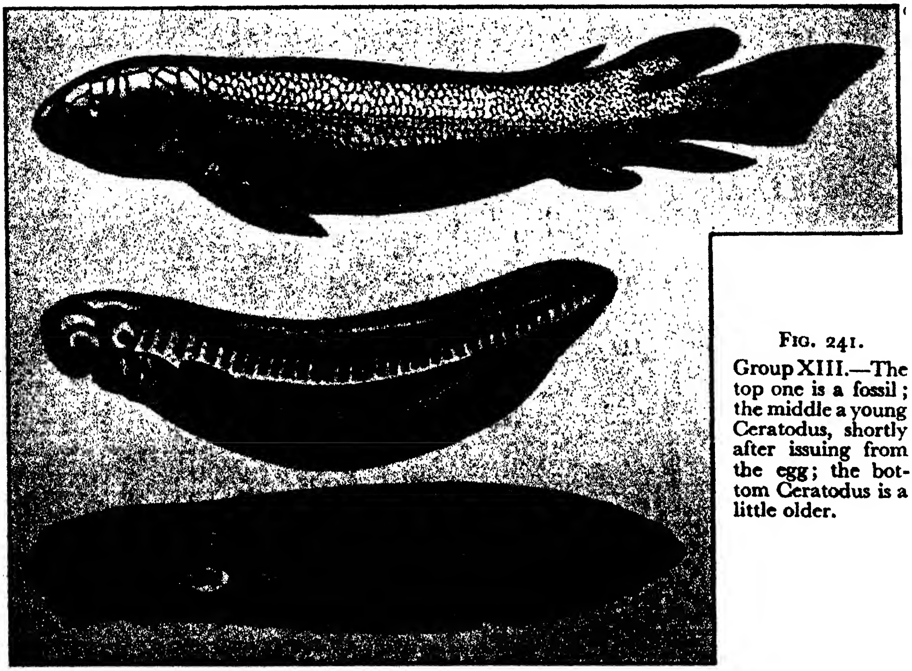


FIG. 241. Group XIII.—The top one is a fossil; the middle a young Ceratodus, shortly after issuing from the egg; the bottom Ceratodus is a little older.

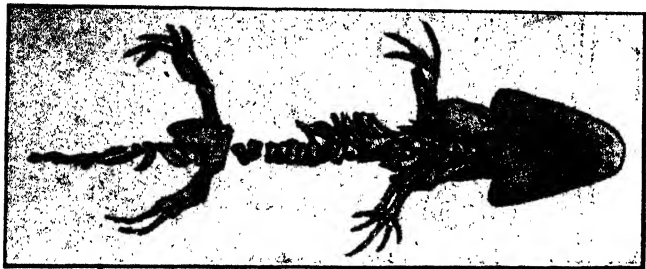


FIG. 242. — Group XIV.—Skeleton of Actinodon, a very early Amphibian, from the Permian strata.

FIG. 243.—Group XIV.—Group of Amphibians of the coal forest period. The big one, in the centre, is Archægosaurus; the one above, Actinodon; the one immediately below, Keraterpeton; the snake-like creature is the Dolichosoma; the head peeping out of the ferns is that of Loxomma.

## GROUP XIV.—AMPHIBIANS

Amphibians are the first terrestrial animals. From the roof-headed ones (Stegocephala) came the reptiles (Figs. 242, 243).

## GROUP XV.—REPTILES

The early reptiles (Figs. 244 and 245) gave off two side-branches, one for the pro-mammals, the other for the birds.

## GROUP XVI.—PRO-MAMMALS

These are the primitive egg-laying mammals, the Monotremes, that link reptiles with the higher mammals (Figs. 246 and 116 (p. 110)).

FIG. 244.—Group XV.—The Pariasaurus (see Fig. 63, p. 67) restored.

FIG. 245.—Group XV.—Probable appearance of the Theromorph Reptile, Dimetrodon. It was found in the lower Permian.

FIG. 246.—Group XVI.—*Echidna Hystrix*, or *Tachyglossus aculeatus*, an Anteater of Australia, Tasmania, and New Guinea. *Zaglossus* is another spiny anteater, confined to New Guinea.

*F. W. Bond.*

## Group XVII.—The Marsupials, or Pouched Animals

Marsupials are a very ancient and widely distributed group. They were certainly present in Cretaceous–Eocene times among the *Multituberculata* and *Plagiaulacidæ*, though what part, if any, they played in the evolution of modern mammals is uncertain (Figs. 247 and 248).

## Group XVIII.—Insect-Feeders (Insectivores)

The consensus of opinion among zoologists favours the view that one of the earliest mammalian ancestors of man *and* ape was an insectivorous animal of the tree-shrew type (Figs. 249, 250).

Fig. 247.—Group XVII.—*Didelphys Marsupialis,* the common Opossum of S. America. It is three to five times larger than any other Opossum. It is one of the great Order of Marsupials, and flourishes from the U.S. as far south as Patagonia. As is seen, the tail is long and prehensile, even amongst their young. The pouch, so characteristic of the Kangaroo marsupial, is lacking, the young being carried on the mother's back and their tails being coiled around hers as a kind of "strap-hanging" support.

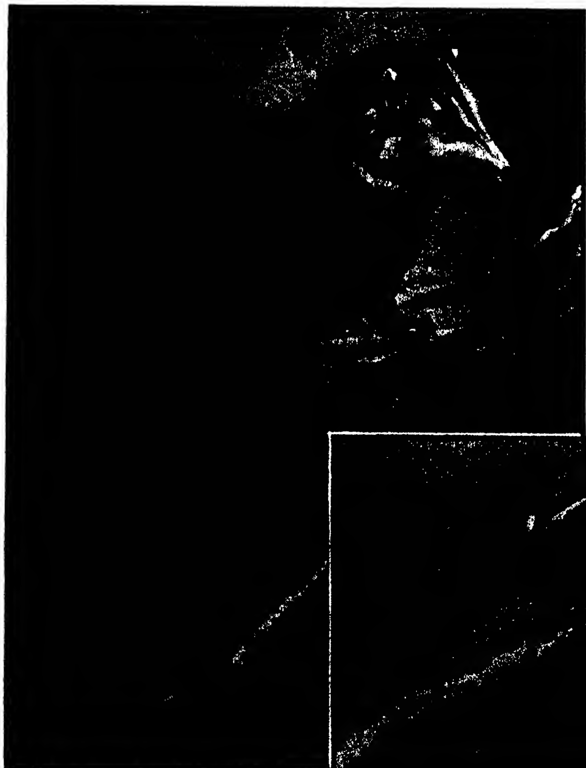


Fig. 248.—Group XVII.—*Tarsipes Rostratus,* a long-snouted phalanger of W. Australia, which has a prehensile tail and a prehensile tongue.

FIG. 249.—Group XVIII. —Pen-tailed Tree Shrew. An arboreal Insectivore, a primitive Order of the true mammals, eutheria. It feeds on leaves and insects. The brain is smooth, representing a low level of organization. Probably a direct descendant of the early common ancestor of Man and Ape.

## GROUP XIX.—LEMURS

These creatures are, so to speak, monkeys in the making; hence one of their names, "half-apes" (Fig. 251). They are for the most part nocturnal animals peculiar to the tropical forests of the Old World. Their digits are flattened and bear flat nails, with the exception of the second digit of the foot, which has a long, thin claw.

## GROUP XX.—PLATYRRHINE MONKEYS

The flat-nosed monkeys are found only in America (Fig. 252). The group comprises two families—the *Hapalidæ*, or marmosets, common in Brazil; and the *Cebidæ* of tropical America, which likewise flourish in the forests of Brazil.

FIG. 250.—Group XVIII. —The *Myogale*, or Desman (Musk Shrew). Connects the moles with the shrews. It is an aquatic Insectivore, a modern representative of the early common ancestors of all mammals.

*F. W. Bond.*

FIG. 251.—Group XIX. — *Microcebus*, the Dwarf Mouse Lemur. Though linked to the Insectivores on the one hand, they have strong affinities with Tarsius, monkeys, apes and men on the other hand, being, in fact, a sub-Order of the great Order Primates. They possess an opposable thumb and great toe, breasts situated on the chest (*Chiromys* excepted); hemispheres of brain are slightly convoluted, and the simian fissure is present. They are small, furry, big-eyed, nocturnal animals. They bring forth one at a birth. They are of great interest in linking up the anthropoidea with the lower mammals.

## GROUP XXI.—CATARRHINE MONKEYS

The down-nosed monkeys and apes belong to the Old World (Figs. 253–256). They are more nearly related to man than the flat-nosed monkeys of the New World. The difference between the lowest monkey and the highest man-like ape, the chimpanzee, is greater than the difference between the highest ape and the lowest man. The Catarrhini include the African baboons, the highly-coloured mandrill, the macaques, the tailless Barbary ape of N. Africa and Gibraltar, the sacred apes of India, the quaint Proboscis monkey of Borneo, and the African Colobus and Cercopithecus. Most of them have cheek-pouches. This group also

FIG. 252.—Group XX.—*Alouatta*, the Red Howler of S. America. It belongs to the Family *Cebidæ* of the Platyrrhine monkeys: sub-Order, Anthropoidea; Order, Primates. This Howler has diverticula from its larynx, as well as a distinct hyoid bone in the throat—both mechanisms that act as reverberations for amplifying the call it emits.

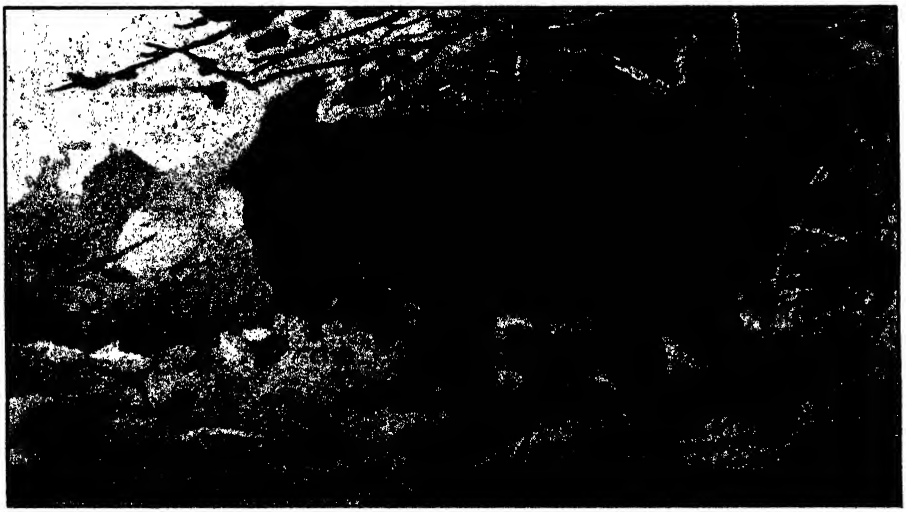


FIG. 253.—Group XXI.—*Cynopithecus Niger*, the Celebesian Black Ape. The group is sometimes referred to as cynomorphi, because of their dog-like faces.

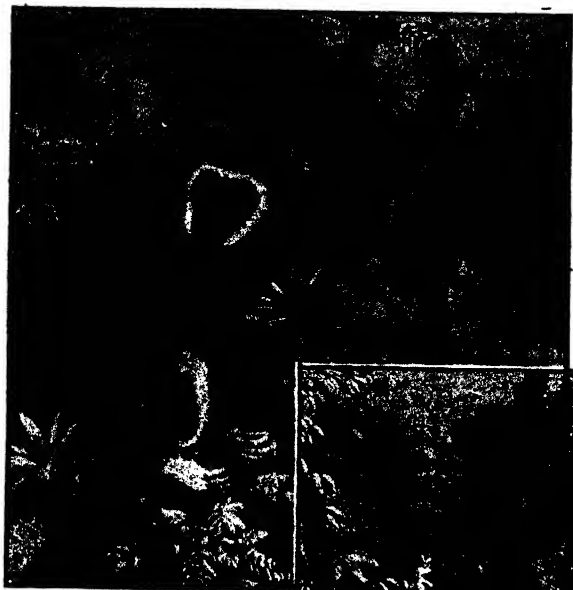


FIG. 255.—Group XXI.—(Left) *Hylobates Lar*, the White-handed Gibbon of the upland forests of Malay. They are tall, thin apes, only about 3 feet in height. They are fond of walking erect when on the ground or a large branch. They can make most prodigious leaps from tree to tree, and have been seen to catch a bird on the wing while doing so.

FIG. 254.—Group XXI.—*Simia Satyrus*, the Orang-Utan of Borneo and Sumatra. This "Old Man of the Woods" constructs a temporary shelter in the trees. The male is about 4 feet in height. Note the rain-shedding hairs of the arms, all sloping towards the elbow. They walk on their knuckles and outer sides of the feet. The Orang is more like Man in the structure of his brain than any other ape. Like the Howlers, the Orang possesses large air-sacs in connection with its larynx to amplify its call. The Orang is probably the first of the Primates to discharge large-bore projectiles at their foes, for they have been known to hurl the heavy durian fruit at human beings and compel them to make a hasty retreat.

contains the Family Simiidæ, or Anthropoid apes, and a fifth Family, the Hominidæ, with the sole genus Homo. The Simiidæ include the gorilla, chimpanzee, the orang-utan, and the gibbon. With the exception of the last-named, who walk on their soles, the Simiidæ walk on the outer edges of their feet.

FIG. 256.—Group XXI.—The Chimpanzee (*Anthropopithecus*), the most teachable of all the man-like apes. Their normal habitat is West and Central Equatorial Africa. They live in families and make nests in trees.

The Family Tree of Man (Fig. 257) is given to show some of our *nearer* relations. In studying the human pedigree by means of this genealogical tree it should be borne in mind that the names on the trunk represent the type-group of animals through which man has evolved, and they are necessarily *fossils*, while the names towards the ends of the branches that reach the top line stand for *living animals*. Branch lines that fail to reach the top represent extinct apes, men, and men-apes.

It is hardly necessary to say that the diagram does no more than give a bird's-eye view of man's genealogical tree since the Family of the first primitive jumping-shrew mammaloid, of the late Cretaceous days, began to split up into the many branches leading to existing mammals.

Fig. 258 illustrates in diagrammatic form the Prehistoric Culture Periods and their relationship to the Geologic, Humanoid, and Historic periods.

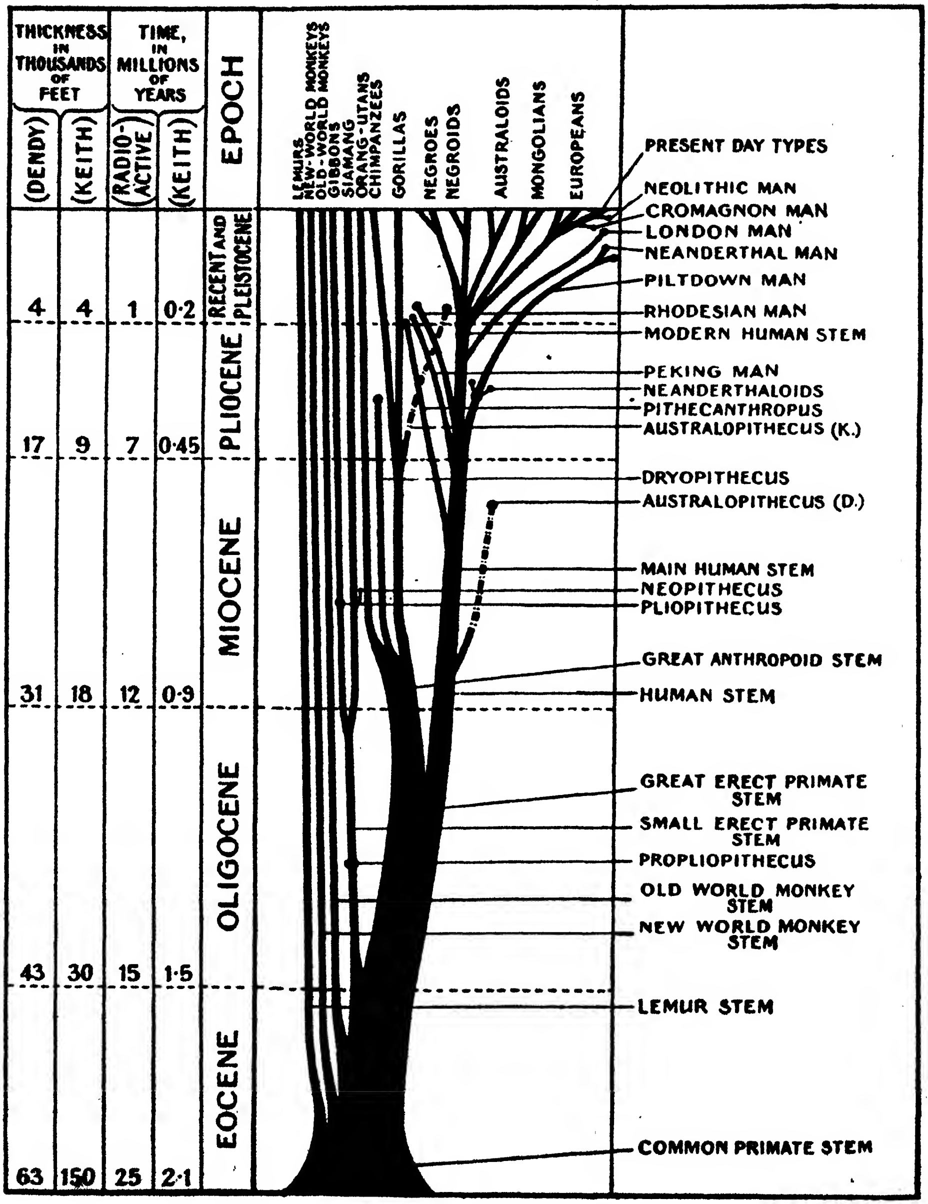



FIG. 257.—Genealogical Tree of the Primates. (After *Keith*.)

The diagram also gives geological time-scale and rock-thickness (after authorities stated). Australopithecus (K.) and (D.) indicate the positions of this South African (Taungs) Ape-man with Australoid features assigned by Professors Keith and Dart respectively.

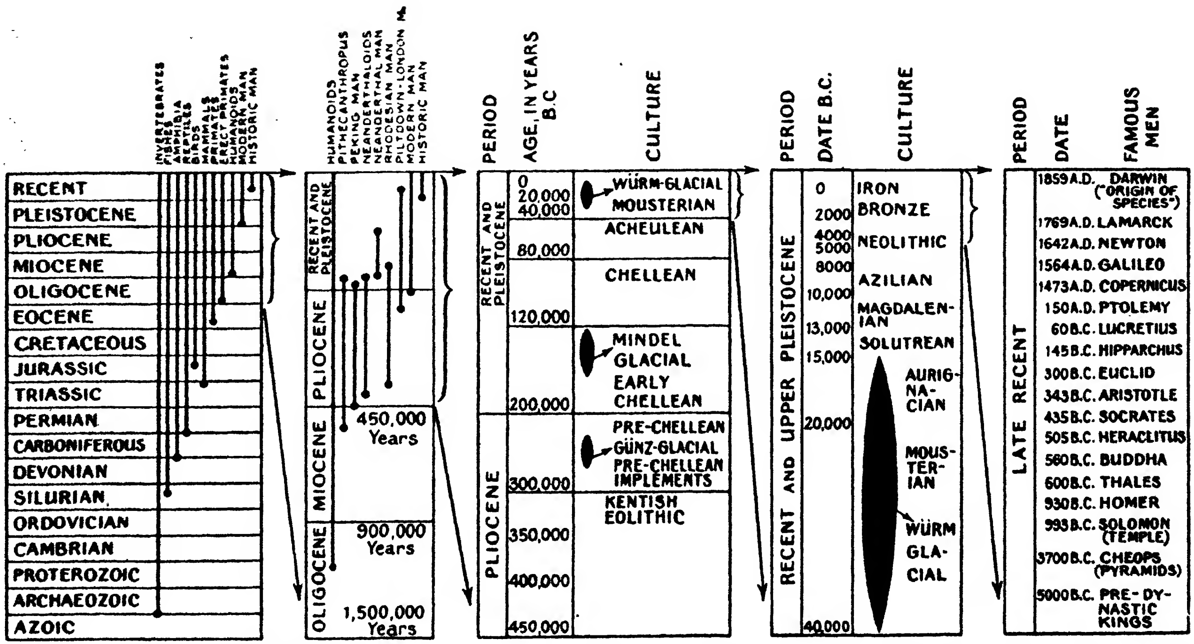
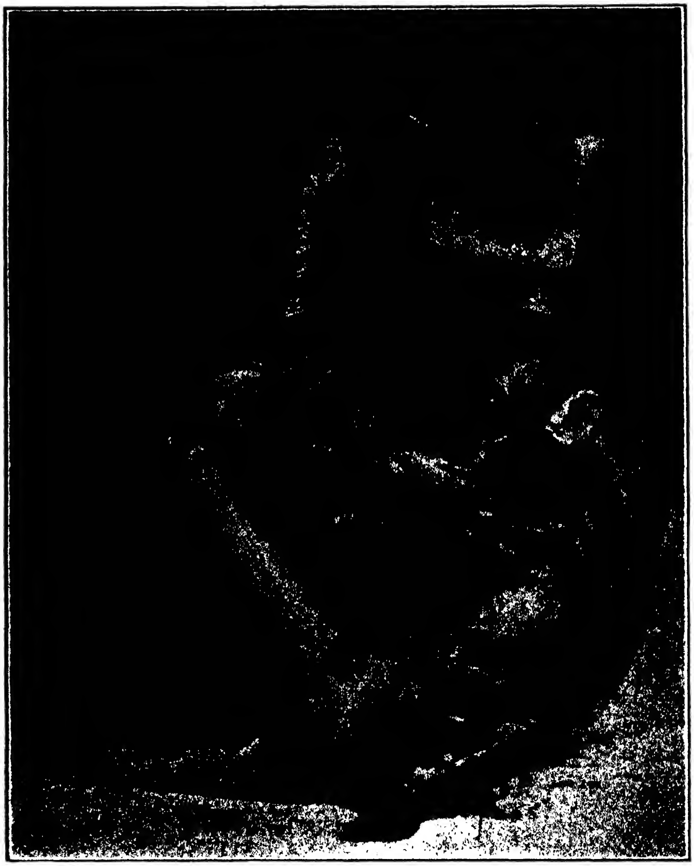



FIG. 258.—Diagram to illustrate Prehistoric Culture Periods and their relation in time to Geologic and Humanoid Periods on the one hand, and to the Historic Period on the other. (The Cultures and Humanoid Time Scales are after *Keith*.)



Parental Love.

The gentle yet mighty power that protects and preserves the higher types of life.

(From *Creation by Evolution*, ed. by Frances Mason.)

Perhaps the fittest comment to this touching picture is:

" Can a mother's tender care
Cease towards the child she bare."

## SOME BIOGRAPHICAL SKETCHES

It will be useful to furnish a few particulars of some of the illustrious men whose works have, directly or indirectly, helped to establish the law of Evolution by providing evidence or proof of its operation throughout all phenomena comprised within the sphere of human knowledge.

ALLEN, CHARLES GRANT (1848–99), was a remarkable combination of scientist and novelist. He wrote *The Evolutionist at Large*, *Vignettes from Nature*, *Charles Darwin*, and *The Evolution of the Idea of God*, the last-named being undoubtedly his greatest achievement.

ARRHENIUS, SVANTE (1859–1927). Swedish chemist and astrophysicist. He was one of the first astronomers to stress the importance of the disaggregative effects of light-pressure and radiation-pressure on minute particles of matter in counter-balancing the aggregative effects of gravitation. Pub. *Worlds in the Making*, *Life of the Universe*—both classics in stellar evolution.

BAER, K. E. VON (1792–1876). Russian biologist; discovered the ovum of mammals in 1827; he also described the three primary germ-layers—ectoderm, mesoderm and endoderm—in the vertebrate embryo. He enunciated "von Baer's law," that development is a progress from the general to the special—a law that profoundly influenced Herbert Spencer's work.

BERNARD, CLAUDE (1813–78). French physiologist of the mechanistic school. His famous *Phenomena of Life* exhibited a revolutionary advance of thought.

BLAND-SUTTON, Sir JOHN (1855–1936). Pathologist and gynecological surgeon. One of the pioneers who boldly carried the principles of Evolution into the domain of medicine and surgery. Pub. *Evolution and Disease*, *Man and Beast in Eastern Ethiopia*.

BON, GUSTAVE LE (1841–1931). Made a special study of the "mass-," or "herd-mind." Pub. *Evolution of Matter*, *Evolution of Forces*, *Psychology of the Crowd*, all evincing a mechanistic outlook on life.

BOSE, Professor Sir JAGADIS CHANDRA, F.R.S. (1858–1937). Pub. *Response in the Living and Non-living*, *Life-movements in Plants*, *Plant-response*.

By means of his personally-devised and exquisitely sensitive electrical apparatus he proved that "irritability"—that is, response to environmental stimuli—is not the prerogative of animals and plants, but extends into the so-called dead, inorganic world. He showed that metals, for example, not only get "fatigued" if "over-worked," but can be "poisoned," or thrown into a "non-irritable" and inert condition wherein their normal response to stimuli fails.

BUFFON (1707–88) may be called the naturalist who laid the basis of modern Evolution in zoology and botany. He first pointed out, on a broad scale, the mutability of species in relation to changes of environment.

BURBANK, LUTHER (1849–1926). Botanist and naturalist. Pub. *New Creations in Fruits and Flowers*, *How Plants are trained to Work for Man*. By his hybridization, grafting, and crossing experiments generally, he evolved numerous new fruits and flowers, and, by ruthless elimination of the unfit (for his purpose), produced stoneless plums, thornless cacti, rapid-growing walnut trees. He also increased the scent of many flowers. This "Wizard of fruits" was a firm believer in the transmission of acquired characters.

CLODD, EDWARD (1840–1930). Folk-lorist. A pioneer writer on Evolution, who devoted a great part of his life to the exposure of superstition in its several guises. Pub. *Childhood of the World*, *Childhood of Religions*, *Story of Creation*, *Story of Primitive Man*, *T. H. Huxley*, and *Primer of Evolution*.

COPE, Professor E. D. (1840–97). One of the leading comparative anatomists of

America. Wrote extensively on Evolution. Pub. *Primary Factors of Organic Evolution.*

COPERNICUS (1473–1543) was born in the little town of Thorn, in Russia. He taught the then revolutionary doctrine that it was the earth that moved, while the sun and stars were at rest. On this account, about 1531, he was ridiculed on the stage and described as a fool by Luther for going against the Bible, while Melanchthon hinted that his opinions should be suppressed. Publication of his great work *The Movements of Celestial Bodies* was only completed in time for the book to be placed in his hands on the day of his death, so that he was beyond the reach of the subsequent fury of his persecutors. From his day onwards it had to be admitted that the earth was but a somewhat insignificant planet rotating on its axis and revolving around a central sun which we now know is 332,000 times more massive than the earth.

CRILE, Professor GEORGE W. (1864–1943). Made a special study of the organs of internal secretion—the hormone, or endocrine glands—and the part they play in the manifestation of the emotions—fright, joy, anger, love, etc.

CUVIER, GEORGES (1769–1832). Though one of the greatest geologists of the age, he rejected the theory of Evolution, and, being on the side of conventionalism and authority, dominated zoological science for half a century.

DARWIN, CHARLES (1809–82). On November 24, 1859, occurred what may fairly be called the most important event in the history of biology—the publication of his *Origin of Species.* Within twenty years this work converted the whole scientific world to the general doctrine of transformism. The theory of Natural Selection, the Survival of the Fittest, or the preservation of favoured races in the struggle for life, was first conceived by Darwin in 1838, but it was not till 1858 that public announcement of it was made simultaneously by himself and Wallace. Both naturalists had, however, been anticipated by Dr. W. C. Wells in 1813, and by Patrick Matthew in 1831, though neither Darwin nor Wallace knew of the fact. But, whatever others may have discovered, it was Darwin who first convinced men of the truth of Evolution. In 1842 he went to live at Down House, Downe, near Beckenham, in Kent, where he patiently continued his researches into the evolution of animals and plants. Thanks to an appeal for funds for the preservation of Down House, made in the course of his Presidential Address to the British Association on August 31, 1927, by Sir Arthur Keith, and the prompt and generous response thereto by the late Sir Buckston Browne, Down House has become the property of the nation, and it is now possible for all to see Darwin's study, garden, and grounds almost as they were when he was alive. It may be truly said, of this greatest of men, that he altered the centre of gravity of thought and "lifted empires off their hinges."

DARWIN, ERASMUS (1731–1802), was the grandfather of Charles Darwin, and was born at Elton, near Newark. In his *Zoonomia* he advanced the view that all animals originated from some one specially-created organism, whose descendants were permitted to evolve by means of *adaptation to environment, elimination of the unfit,* and the *transmission of acquired characters.* He thus anticipated Lamarck, Spencer, and his illustrious grandson. However, in his scheme of Evolution, Natural Selection appears to be entirely overlooked.

EINSTEIN, ALBERT. (*B.* 1878.) German scientist. When only sixteen years of age he read a mathematical paper which astonished scientists by its profundity of thought. He published his first work on Relativity in 1905 while attached to a Swiss university, and his great one, which caused all the furore, ten years later while working in a laboratory in Berlin. Einstein is not the "inventor" of Relativity, for this has been a subject of philosophic discussion for many years, but his is the credit for having made the theory, *in certain instances,* square with observed facts of nature. For example, by it he has accounted for the puzzling annual shift of the perihelion of Mercury's orbit. Take, again, the question of *gravitation* and *inertia.* In a vacuum, all bodies, whatever their mass, behave similarly as regards inertial and gravitational

forces, for both are due to a common cause—acceleration. A person in a fixed, closed chamber in a gravitational field can sense all phenomena due to gravity, but should the whole chamber fall through space with acceleration normal to the gravitational force, he, as well as all other objects with him, *would have no weight.* The safer and more truly scientific attitude is to reserve judgment upon some of the conclusions recently enunciated by those scientists who have identified themselves with Relativity, and to decline to be waved about by every wind of doctrine. Brilliant discoveries were made and predictions fulfilled on the assumption that the earth was a finitely bounded flat plane; also on the assumption that it was a sphere around which a starry vault revolved; and, again, on the assumption that it was an almost infinitesimal speck amid an infinite number of other bodies scattered through an eternally existent and infinitely extended space. Hence the argument that because predictions based on some hypothesis prove correct, therefore the hypothesis must be true, is entirely fallacious. Inferences as to the cosmos that are drawn from mathematics, with its manipulations of abstract symbols such as zero, plus and minus infinities, and the square root of minus one, which represent no possible concretes, are necessarily suspect.

The great work of Einstein has been the development and correction of that of Newton. It was on May 19, 1919, during the solar eclipse, that one of Einstein's predictions—the observable deflection of light by large cosmic masses—was put to the test and confirmed. Einstein, so far as one can gather, conceives of the universe in pure space-time terms—as a four-dimensional continuum in which TIME is the *fourth dimension*, SPACE accounting for the primary three extensions. The masses of matter scattered throughout space become, in Einstein's view, evanescent crumplings in a four-dimensional continuum!

FISHER, R. A., F.R.S., F.R.S.S., Sc.D., D.Sc. (*B.* Feb. 17, 1890.) Has carried out a great deal of valuable research work into the functions of the genes and chromosomes. Has been Professor of Genetics at the University of Cambridge. Pub. *The Genetical Theory of Natural Selection.*

GALILEI, GALILEO (1564–1642), the great Italian astronomer, accepted and improved upon the system of Copernicus, and in consequence suffered great persecution at the hands of the Roman Catholic Church. He was finally examined by the Inquisition on June 21, 1633, under threat of torture, and " was convicted of believing and holding the doctrines—false and contrary to the Holy and Divine Scriptures—that the sun is the centre of the world, and that it does not move from east to west, and that the earth does move and is not the centre of the world." He was required to " abjure, curse, and detest the aforesaid errors " on his knees and was condemned to the " formal prison of the Holy Office " during the pleasure of his judges. Finally, he was ordered to repeat the seven penitential psalms once a week for three years. It is said that when Galileo rose from his knees, after his enforced perjury, he stamped his foot and whispered to a friend, " *Eppur si muove* " (" Nevertheless, it (the earth) *does* move "). It has become " fashionable " of late to deny the story; for instance, the Hon. Bertrand (Lord) Russell says: " It is not true that, after reciting this abjuration, he muttered: '*Eppur si muove.*' It was the world that said this—not Galileo." (*The Scientific Outlook*, 1932.) Old and blind, Galileo died January 8, 1642, nearly seventy-eight years of age.

Though Copernicus had found the sun to be the centre of our solar system, he still made use of " the epicycles and eccentrics of the Greeks," and it was Kepler (1571–1630) to whom we are really indebted for their rejection.

GALTON, FRANCIS, F.R.S. (1822–1911). A cousin of Charles Darwin. He originated the method of identification by means of finger-prints. As Mendel had done for plants, Galton worked out the heritage proportions present in animal offspring. He showed that the two parents contribute between them, *on the average*, one-half of the total heritage, the four grandparents a quarter, the eight great-grandparents an eighth, the sixteen great-great-grandparents a sixteenth, and so on, the sum of the ancestral conditions being expressed by the series

$$\tfrac{1}{2} + (\tfrac{1}{2})^2 + (\tfrac{1}{2})^3 + (\tfrac{1}{2})^4 \ \ldots \ \text{etc.} = 1.$$

GEGENBAUR, KARL (1826–1903), is described by Haeckel as "the comparative anatomist who surpassed all other experts of this science in the second half of the nineteenth century." His great work was *The Comparative Anatomy of the Vertebrates.*

He showed that the nerves proceeding from the base of the brain are modifications of spinal nerves. It was Gegenbaur who first suggested that the wings of insects originated as modifications of the leaf-like tracheal gills. His theory presents certain difficulties, but none of them is of serious weight.

GOETHE, JOHANN WOLFGANG (1749–1832), the great German poet, was a keen supporter of Evolution. He introduced the term "morphology," to which science he made important contributions.

He recognized the importance of vestigial organs, and correctly predicted the presence of a premaxilla in man—the absence of that bone in the *adult* human skull being hitherto considered as distinctively separating man from the other Primates!

GOODRICH, E. S., F.R.S. (1868–1946.) Professor of Zoology. Studied under, and subsequently became assistant to, Professor Ray Lankester, F.R.S., whom he later succeeded as Linacre Professor of Zoology and Comparative Anatomy at Oxford University. Goodrich has been described as the greatest Comparative Anatomist of the time. His speciality was the nephridium, or primitive kidney, in the Annelid Worms and Amphioxus, and in proving its distinction from the Cœlomoduct. He showed the correct position of the Archi-annelida in the phylogeny of invertebrates. He wrote a text-book on the Holothuroid Echinoderms, and on Fishes. One of his earliest works was on fossil mammalian jaws. Perhaps the most famous of his writings was *Studies on the Structure and Development of Vertebrates.* From 1915 to 1923 he was zoological secretary to the Linnean Society of London. In 1913 he married Dr. Helen L. M. Pixell, with whom he collaborated in researches on the Protozoa. He was made F.R.S. in 1905 and received the Linnean Medal, 1932, and the Royal Medal 1936. D.Sc. Oxford and Dublin. LL.D. Dublin.*

GREGORY, Sir RICHARD A., F.R.S., F.R.A.S., D.Sc. (*B.* Bristol, Jan. 29, 1864.) Emeritus Professor of Astronomy, Queen's College, London. Assistant Editor, *Nature*, 1893–1919; editor, 1919–1939. Pres. British Association 1940–1944. Revised Huxley's *Physiography*, and has written extensively on that subject. He is also the author of *Religion in Science and Civilization* and other works, and of several textbooks of physical geography, physiography, physics, chemistry, and general experimental science.

HAECKEL, ERNST (1834–1919). One of the greatest Evolutionists and the first German to accept the discovery of Darwin, he did more than anyone in Germany to demonstrate its truth. He was the first modern zoologist to attempt the classification of animals on a frankly evolutionary basis, and to him we owe the terms "phylogeny" and "ontogeny," "cœnogenesis" and "palingenesis," and the fruitful gastræa theory, according to which the gastrula is the ancestral form of all the Metazoa. Among his many works are *The Natural History of Creation, The Evolution of Man, The Riddle of the Universe,* and *The Wonders of Life.*

HALDANE, J. B. S., F.R.S., is one of the foremost geneticists of the day. He is the son of the physiologist, J. S. Haldane, F.R.S., a great authority on the physiology of respiration. J. B. S. Haldane became a Professor of Biometry at University College, London, in 1937. He was born on November 5, 1892. Reader in Biochemistry, Cambridge University, 1922–1932. Fullerian Professor of Physiology at the Royal Institution, 1930–1932. Professor in Genetics in the London University. He was President of the Genetical Society, 1932–1936. He has written largely on Evolution and biology. In addition to his brilliant researches in intracellular physiology, he is an eminent mathematician. He is at present engaged in research work at the

* The Author is indebted to the Editor of *Nature* and to Dr. G. R. DE BEER, F.R.S., for the above information.

Rothamsted Experimental Station, Harpenden, Herts. Author of *Science of Everyday Life*, *New Paths in Genetics*, *The Causes of Evolution.* To the author it is somewhat of a paradox to find this scientist, who for many years has been constantly engaged in biological researches, every one of which has been conducted in terms of mechanism and Materialism, finding himself capable of writing the following:—

"I confess that when I think of the mechanistic theory of life, it is only my personal respect for those who have held it, or still hold it, that prevents me from regarding it with scorn. It seems to me to explain nothing and only to lead physiologists and clinicians into dead ends."

HELMHOLTZ, VON (1821–94). Distinguished German physicist; discovered the *Conservation of Energy* in 1847.

HOOKER, Sir JOSEPH DALTON (1817–1911). A great botanist who added considerably to our knowledge of the distribution of plants. He was director of Kew Gardens for twenty years, and as President of the British Association, in 1868, supported the views of Darwin on Evolution.

HUBBLE, E. P., Ph.D., Hon. D.Sc. Ox. (*B.* Nov. 20, 1889.) Astronomer Mt. Wilson Observatory. He has carried out many researches in the field of the extragalactic nebulæ, and very few men have plumbed the deeps of space to the extent he has, and to each fresh penetration he achieves he gives the answering cry: "No bottom!"

HUXLEY, JULIAN, F.R.S., M.A., D.Sc. (*B.* June 22, 1887). Zoologist. Grandson of Thomas Huxley. Past Professor of Zoology, King's College, London. Lecturer in Zoology, King's College, London, 1927–35; Secretary Zoological Society, London, 1935–1942. Dr. Huxley has written and lectured widely on evolutionary subjects. His works include *The Individual in the Animal Kingdom* (1911), *The Stream of Life* (1926), *Religion Without Revelation* (1927), *Animal Biology* (with J. B. S. Haldane), (1927), *The Science of Life* (with H. G. and G. P. Wells), (1929), *Elements of Experimental Embryology* (with G. R. de Beer) (1934), *Evolution Restated* (1940), and *Evolution : the Modern Synthesis* (1942).

HUXLEY, THOMAS HENRY (1825–95), ranks as one of the foremost of the discoverers and teachers of Evolution. His wonderful ability, industry, fearlessness, and eloquence, fitted him for the position of leader in the war against prejudice which broke out on the publication of Darwin's *Origin of Species*. Darwin used to say there were three judges by whose decisions he always abided—Lyell, Hooker, and Huxley.

JEANS, Sir JAMES, F.R.S. (1877–1946). Astronomer. Second Wrangler 1898. Pub. *Problems of Cosmogony*, *Astronomy and Cosmogony*, *The Universe Around Us*, *Eos*, *The Mysterious Universe*, *The Stars in their Courses.* The last four works have made an especial appeal to the more thoughtful section of the reading public who evince a desire to know something about the structure and evolution of the cosmos. Sir James Jeans saw the origin of our planets in discrete condensations occurring in an enormous cigar-shaped filament of gas torn out of our primordial sun by some passing huge star. He assumed a space-time finiteness to the cosmos, a view that would appear to predicate its appearance in the past out of nothing. As regards the future, Sir James resuscitated the theory (discarded by many cosmologists) known as "thermal extinction," the *Warmetod*, or "heat-death," of Clausius, and as the "degradation of energy" of Kelvin. His general argument would appear to imply that, since work in the human laboratory is invariably accompanied by degeneration of temperature to a lower and less available level, it must be accompanied by a similar degeneration throughout the cosmic laboratories. The entropy (or thermodynamic function) of the universe is, he thought (with Clausius), constantly increasing and tending to a maximum; the whole cosmos is running down as regards work-availability, and a time must eventually arrive when it will be represented as a universally warm—neither hot nor cold—clod! Such view is obviously in contradiction to that idea of eternal continuity which is the foundation of the mechanical equivalent of heat, and it would, moreover, appear to ignore those forces in the universe which maintain entropy at a constant mean. If we have

read Sir James aright, it would also seem that he inclined to the belief in a principle of *indeterminism* as regards, at any rate, the ultra-microscopic world of atoms. Such a view necessarily commits the holder to belief in spontaneous—that is, self-caused—action; in other words, to belief in an effect without antecedent cause. The consistent student of Evolution will do well to hold a watching-brief concerning some of the conclusions arrived at by this distinguished mathematician.

JOULE, JAMES PRESCOTT. *See* Lavoisier.

KEITH, Sir ARTHUR, F.R.S., M.D., F.R.C.S., D.C.L., D.Sc. (*B.* Feb. 5, 1866.) Anthropologist. Conservator of Museum, and Hunterian Professor, Royal College of Surgeons; Rector, Aberdeen University; Pres. Royal Anthropological Institute, 1912–1914; Master, Buckston Browne Research Farm; President of the British Association, 1927; Fullerian Professor of Physiology, 1917–1923. Sir Arthur has written profusely, both technically and popularly, on evolutionary subjects. For its outspokenness on the implications of Evolution, his notable address as President of the British Association, in 1927, ranks with that of Tyndall at Belfast, in 1874, and with the utterances of Huxley and Hooker at the Oxford meeting in 1860. Sir Arthur's numerous evolutionary works include *Introduction to the Study of Anthropoid Apes* (1896), *Human Embryology and Morphology* (1901), *Ancient Types of Man* (1911), *The Human Body* (1912), *Antiquity of Man* (2nd edit. 1925), *Engines of the Human Body* (2nd edit. 1925), *Religion of a Darwinist* (1925), *Concerning Man's Origin* (1927), *New Discoveries Relating to the Antiquity of Man* (1931), *Darwinism and Its Critics* (1935), *Stone Age of Mt. Carmel Human Fossil Remains* (with T. D. McCown, 1939), and *Essays on Human Evolution* (1946).

KEPLER, JOHANN (1571–1630) will be for ever famous for the working out of his three planetary laws:—

(1) Planets move in ellipses.
(2) The straight line joining the centres of the sun and planet, the "radius vector," sweeps over equal areas in equal times.
(3) The squares of the periodic times of the planets are proportional to the cubes of their distances from the sun.

LAMARCK (1744–1829) was not only a distinguished zoologist and palæontologist, but may also be looked upon as the chief of the pre-Darwinian Evolutionists. In his *Philosophie Zoologique*, published in 1809 (the year in which Charles Darwin was born), he completely rejected the idea of the fixity of species, and endeavoured to explain the transformation of one form into another by the operation of known causes; of these he attached most importance to the principle of use and disuse, and he was a firm believer in use-inheritance.

Lamarck was violently attacked and ridiculed by the orthodox biologists, especially by Cuvier, and even Charles Darwin alluded disparagingly to his work. Lamarck was the first zoologist to formulate a definite evolutionary theory of descent, and though many of his assumptions are still debatable, the value of his immense contributions to Evolution has not yet received adequate recognition. He was a strong upholder of the theory of the Transmission of Acquired Characters. He died poor, neglected, and blind.

LANKESTER, Professor Sir RAY, F.R.S., D.Sc. (1847–1928). Zoologist. Professor of Zoology and Comparative Anatomy at the University of London, President of the British Association, Director of the Natural History Department of the British Museum, and Vice-President of the Royal Society. He carried out a vast amount of highly specialized research work in zoology, more especially on the invertebrate side. Edited the *Scientific Memoirs of Huxley* and translated Haeckel's *History of Creation.* Wrote widely for the general public on evolutionary topics, especially in his *Kingdom of Man, Extinct Animals, Science from an Easy Chair*, and *More Science from an Easy Chair.*

LAVOISIER, A. L. (1743–94). Chemist. Famous for his discoveries in connection with Oxygen (1775) and for his enunciation of the *Law of the Conservation of Mass*:—"*Matter is never created nor destroyed* in any chemical or other process." It was not

until 1842 that Mayer, and quite independently (in 1847) von Helmholtz, discovered the *Law of the Conservation of Energy*. By energy is meant capacity to do work—that is, ability to effect a change. Energy appears in many guises: potential—kinetic—heat—light—electric—and chemical energy. A definite quantity of energy is always a product of two factors: a *capacity* factor (length, volume, mass, caloric) and an *intensity* factor (weight, force, pressure, temperature, electromotive force). The types are transformable one into another—electrical into heat, and so on—but a given quantity of one form is always strictly equivalent to a definite quantity of another form. These laws were clinched, so to speak, in 1843, when Joule made his great discovery of the *mechanical equivalent of heat*. He proved that a definite amount of work produced a definite amount of heat. He showed, for example, that the fall of a pound weight through a distance of 772 feet sets free a quantity of mechanical energy that will raise the temperature of a pound of water 1° Fahrenheit. Finally, M. Carnot and M. Hirn reversed the process and demonstrated that *one degree Fahrenheit added to the temperature of a pound of water can perform work equivalent to raising a weight of* 1 *lb. to a height of* 772 *feet.*

Some people seem to have jumped to the conclusion that modern physics disproves the Laws of the Conservation of Mass and of Energy. It does nothing of the kind, despite its resolution of "matter" (in the familiar forms that act on our sense-organs) into definite entities, "electrons" and "protons," and despite the proof that these electrons and protons are further transformable into ENERGY. The general principles of the conservation of mass *and* energy are even firmer to-day than when Lavoisier, Mayer, and Helmholtz first enunciated them. Our conceptions of the fundamental nature of "matter" and "energy" have, no doubt, undergone radical change, but the one solid fact remains: that the sum-total of matter-energy in the cosmos is a constant quantity—uncreatable and indestructible. This does not mean that "matter" or "energy," as familiar to us, is uncreatable and indestructible, but simply that where one is "created" the other is "annihilated"; indeed they are, so modern physicists assure us, convertible. Under the tremendous temperatures and pressures in the interior of certain stars some of the planetary electrons surrounding the atom are torn altogether away from the atom, and naked nuclei alone are left, or at least nuclei with only a K-ring electron.

LINNÆUS (1707–78), the famous Swedish naturalist, wrote the *Systema Naturæ*, which was the turning-point in modern zoology and botany. He was an industrious collector of facts, and wrought important changes in classification. His ambition was to arrange animals in a *natural system* conformable to the fixity of species since their creation as described in *Genesis*. When he published the revised edition of his work, in 1766, he left out his fundamental proposition of the earlier works, that *there were no new species*.

LOEB, JACQUES (1859–1924). Zoologist. Late of the Rockefeller Institute. He conducted many wonderful experiments in the artificial fertilization of animals, and his writings show that he held a purely mechanistic conception of life. Pub. *Physiology of the Brain, Dynamics of Living Matter, Mechanistic Conception of Life, The Organism as a Whole.*

LUCRETIUS (95–52 B.C.), in his grand poem *De Rerum Natura* stands forth as an early poet of Evolution. With Empedocles and Epicurus he held a survival-of-the-fittest view of life. Being a Rationalist, he had no place for Centaurs and Chimæras in his scheme of creation, and rejected the teleological for the mechanical conception of nature.

LULL, RICHARD SWANN. (*B.* 1867.) Professor of Biology at Yale University. His *Organic Evolution* is one of the best and most up-to-date works on the subject.

MCCABE, JOSEPH. (*B.* Nov. 11, 1867.) Besides his numerous lectures and addresses, Mr. McCabe has written, in charming style, an immense number of popular books on Evolution. He translated Haeckel's large two-volume work on the *Evolution of Man*. Among his books the following are of exceptional interest to students of

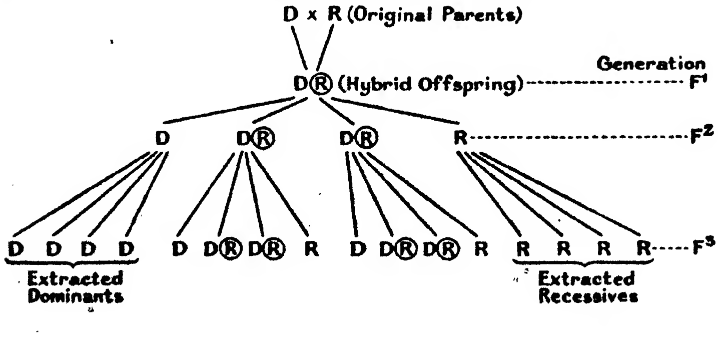
Evolution: *Story of Evolution, Evolution of Mind, Principles of Evolution, End of the World, A.B.C. of Evolution, Evolution of Civilization, Marvels of Modern Physics.*

MAYER, JULIUS ROBERT (1814–78), was born at Heilbronn. In 1842 he consolidated Lavoisier's discovery of the conservation of mass by proving the *conservation of energy*; in other words, he showed that *energy, like matter, is indestructible.*

MENDEL, GREGOR (1822–84). An Austrian monk. The Mendelian theory of heredity is now accepted by all biologists, though during the lifetime of its discoverer it was unnoticed. Even Darwin was unaware of Mendel's work, which would certainly have profoundly modified some of his views on heredity. The simple Mendelian proportions are obviously, at bottom, fixed by laws of mathematical probability. The DOMINANTS (that is, obtrusive characters in an organism) and RECESSIVES (or characters which are present only in latent form, suppressed or concealed) appear in ensuing generations with the mathematical precision with which coloured beads, drawn in pairs at random from a bag containing equal numbers of them, assort themselves. Supposing, for example, that from a bag containing 6,000 black beads (B) and 6,000 white ones (W), thoroughly mixed up, the beads are drawn out blindly, in pairs, and placed on a table one behind the other, it will be found that, on the average, they will come out as follows:

| | | |
|---|---|---|
| 3,000 W | behind | W. |
| 3,000 B | ,, | B. |
| 3,000 B | ,, | W. |
| 3,000 W | ,, | B. |

In other words, the *pairs* will be 3,000 pure white, 3,000 pure black, and 6,000 "hybrids," black and white. Suppose, now, we start with 12,000 seeds taken haphazard from the pods of hybrids resulting from the crossing of green-coloured peas (g) with yellow-coloured ones (y). If these peas be sorted out it will be found that 9,000 are yellow (y) and 3,000 green (g). The proportion is therefore 3 y : 1 g. But this proportion is not really as simple as it looks. These peas if sown, and the resulting flowers strictly fertilized among themselves, behave as follows: the 3,000 green-coloured peas will breed true—that is, they will produce in all subsequent generations nothing but green-coloured peas; they, and their subsequent, pure-bred, green descendants, are termed EXTRACTED RECESSIVES. Of the 9,000 yellow peas, 3,000 will be found to breed true—that is, ever afterwards they will produce nothing but yellow peas; they, and their pure-bred yellow descendants, are called EXTRACTED DOMINANTS. But 6,000 yellow peas are still unaccounted for. It will be found that of these, one-third (that is, 2,000 peas) breed true, producing yellow peas ever after, while the other two-thirds (that is, 4,000 peas) will produce hybrids, or peas that do not breed true; and of these hybrids 3,000 will be yellow and 1,000 green, thus showing the same proportion 3 : 1 as at the start. In such an example the yellow peas show obtrusiveness—they are the DOMINANTS; the green peas, on the other hand, show a more retiring disposition—they are the RECESSIVES. This may be made clearer by a diagram where D and R stand respectively for



" Dominant " and " Recessive," and DR for " Hybrid," which (in our example) is coloured yellow and, therefore, *apparently dominant*, but which holds the green colour, or *recessive character*, in a latent and suppressed state. A circle around the R indicates that the character, though present, is concealed.

MENDELÉEFF, DMITRI (1834–1907). Russian chemist. Professor of Chemistry at St. Petersburg University. Mendeléeff, Newlands, and Meyer, independently of one another, formulated the PERIODIC LAW of the chemical elements, which, by proving the genetic relationship of the elements, has led to the discovery of new elements.

METCHNIKOFF, ELIE (1845–1916). Russian zoologist. Professor of Zoology at Odessa. He was one of the pioneers among writers on Evolution. Metchnikoff will ever be famous for his researches into PHAGOCYTOSIS, wherein he demonstrated the amœba-like behaviour of the white blood cells in seizing and devouring intruders into the tissues of the body, such as microbes and foreign bodies generally. The white blood cells constitute a standing army of policemen and soldiers to protect the organism from invasion by " foreigners." Pub. *Nature of Man*, *Prolongation of Life*.

MILLIKAN, ROBERT ANDREWS, Sc.D. (*B*. March 22, 1868.) American astronomer and astro-physicist. Vice-President of the American Association for the Advancement of Science. For many years he has devoted himself to research into the mysterious radiations pouring into our atmosphere *day and night* from every angle of the heavens. These rays, he thinks, are of a nature conformable with a genesis of hydrogen and helium in the extremely cold depths of inter-stellar space. The radiations which are manufactured in the depths of incandescent suns, consequent upon disintegration of atoms through the high temperatures and pressures there met with (and which, therefore, are the energy-equivalents of the protons and electrons that made up the disintegrated atoms), escape at the surface of the suns and ultimately reach the cold depths of intergalactic space. Here, thinks Millikan, they are synthesized into hydrogen and helium, which in their turn probably undergo further synthesis into the higher elements such as carbon, oxygen, nitrogen, sulphur, etc., which are known to be present in those vastly distant regions. It is, he believes, during such synthetic processes that these excessively short wave-length cosmic rays are first produced to reach our earth, perhaps many thousands of years later. Millikan's theory is much more in keeping with that principle of continuity which appears to underlie all evolutionary processes than is the pessimistic heat-death theory of the universe as postulated by Kelvin, Clausius, and urged by Jeans, for it gives us a self-contained cosmos in which matter that has been broken down and destroyed (as such) in one place is rebuilt in another place. Millikan's theory brings us once more to an infinitely extended, eternally enduring, and ever-fluxing matter-energy cosmos.

MITCHELL, Sir PETER CHALMERS, F.R.S. (1864–1945). Late Secretary of the Zoological Society. He wrote several works on Evolution. Pub. *Outlines of Biology*, *Biological Problems*, *Nature of Man* (tr. Metchnikoff), *T. H. Huxley*, *Evolution and the War*, *Materialism and Vitalism*. It was mainly owing to his enterprise and scientific organization that the Zoo extension at Whipsnade was made, where the public can see animals living in what is almost their natural habitat.

MORGAN, LLOYD, F.R.S. (1852–1936). Biologist. Emeritus Professor at the University of Bristol. Wrote many works on evolutionary biology, in the later ones stressing a principle known as *Emergence*. Pub. *Animal Life and Intelligence*, *Habit and Instinct*, *Animal Behaviour*, *Interpretation of Nature*, *Emergent Evolution*.

NEWTON, ISAAC (1642–1727) accomplished most remarkable work in astronomy, optics, and pure mathematics. He stands forth as one of the greatest men of all time. We are here concerned with his brilliant discovery of the Law of Gravitation, which states that the attraction between two particles of matter is directly proportional to the product of their masses and inversely proportional to the square of their distances apart.

Other astronomers had toiled to show *how* the heavenly bodies moved; Newton

discovered *why*. He held that the centre of the sun is the centre of gravity of the solar system, but not of the universe; that it is at rest relatively to all the planets, satellites, etc. in the solar system, but not in relation to the stars and other heavenly bodies of the universe.

OSBORN, HENRY FAIRFIELD (1857–1935). American palæontologist. Was Research Professor in Zoology at Columbia. Wrote very widely on Evolution. Pub. *From the Greeks to Darwin*, *Age of Mammals*, *Huxley and Education*, *Men of the Old Stone Age*, *Origin and Evolution of Life*.

OWEN, Sir RICHARD (1804–92), was undoubtedly the greatest palæontologist of his age, and, though a bitter opponent of Darwinism (and by no means always over-scrupulous in his manner of attack), his colossal work contributed immensely to the very doctrine he so detested. He was a strong supporter of Oken's erroneous theory of the origin of the skull.

PAVLOV, Prof. IVAN P. (1849–1936). Russian physiologist. His *Conditioned Reflexes* is an epoch-making work; in it he showed that many every-day routine actions, such as dressing, eating, etc., are largely carried out in the absence of consciousness.

PEARSON, KARL, F.R.S. (1857–1936). Galton Professor of Eugenics in the University of London. Conducted a large amount of research work into the mathematics of evolutionary biology and heredity. Pub. *Ethics of Free Thought*, *Chances of Death and other Studies in Evolution*, *Grammar of Science*.

POULTON, E. B., F.R.S., D.Sc. (1856–1943). Zoologist. Professor Poulton was a great authority on mimicry in animals, in which study he was a pioneer. Hope Professor of Zoology at the University of Oxford. Romanes Lecturer. Pub. *Colours of Animals*, *Charles Darwin and the Theory of Natural Selection*, *Essays on Evolution*, *Charles Darwin and the Origin of Species*.

QUINTON, R. Physiologist. Independently with Professor Macallum he conceived the idea that the blood of living animals furnishes a valuable clue to the temperature and composition of the early pre-Cambrian seas. Our "naked" ancestors dwelt immersed in a saline fluid; each of their cells was, consequently, saturated with salt water. When, with the advent of a protective and enclosing membrane or skin, the cells got shut off from direct contact with the sea-water they retained some of it as their "vital fluid," which, circulating, became the blood and lymph streams. These in chemical composition were practically identical with that of the pre-Cambrian sea-water in which the unclosed cells of their ancestors had been immersed. When these aquatic skin-enclosed animals left the seas and became terrestrial they carried with them, so to speak, this modified saline fluid sealed up inside their bodies. Though necessarily re-manufactured at each new generation, heredity has conserved it in more or less the same chemical proportions ever since. Hence it is that our body-fluids generally—the blood in the vessels, the lymph in the lymph-spaces, the tears cleansing the surface of the eye, the lubricating "oil" of our joints, the fluid bathing each cell, the amniotic liquid in which the fœtus is immersed—are, in essence, a dilute sea-water, or what the biochemist terms a "normal saline solution." The pre-Cambrian seas are known to have been less saline than modern seas, and so our body fluids contain a smaller percentage of total salts than do the seas of to-day, but are more or less identical in salinity with those of pre-Cambrian times. Without the regular and constant presence of this miniature salt sea, not one of our cells could live a moment. An amœba or a human blood corpuscle, placed in pure water, dies immediately.

REID, Sir GEORGE ARCHDALL, F.R.S.E. (1860–1929). Sir Archdall was an ardent Evolutionist and a keen fighter against Lamarckians in biology and neo-Relativists in physics. Pub. *Present Evolution of Man*, *Alcoholism: a Study in Heredity*, *Principles of Heredity*, *Laws of Heredity*. A large book on Eugenics and Evolution was being completed when his untimely death occurred. Sir Archdall believed that mankind, through survival of *germ-cells* that are tolerant towards certain poisons intimately associated with civilization (such as alcohol, nicotine, and the toxines liberated by the *Spirochæte pallida*, the protozoon of syphilis, and other "microbes" more or

less specialized for a habitat in man's tissues) and the elimination of germ-cells that are susceptible to them, is gradually acquiring an immunity against such poisons. This is not the transmission of an *acquired character*, for the "selection" of the fitter cells and "rejection" of the less fit ones take place entirely among the germ-cells, irrespective of the body-cells.

ROMANES, GEORGE JOHN, F.R.S. (1848–1894). His works, *Animal Intelligence* and *Darwin and After Darwin*, rendered valuable service.

RUTHERFORD, Lord ERNEST, O.M., F.R.S. (1871–1937). Cavendish Professor of Experimental Physics, Cambridge University. Professor of Natural Philosophy, Royal Institution. One of the pioneers in Radio-Activity of the Elements. Pub. mostly in the Transactions of the Royal Society, *Radio-Active Transformations*, *Radio-Active Substances and their Radiations*.

SCHWANN, THEODOR (1810–82). Professor of Anatomy at Louvain. He rejected the traditional *vitalism* and inclined towards the modern physico-chemical theory of life. It was Schwann who discovered the true nature of fermentation. With Schleiden he made important researches into cell-structure, and both observers noted the many common features of animal and plant-cells—thus paving the way for the future work of Pasteur, Virchow, and Lister.

SHAPLEY, HARLOW, Ph.D., Sc.D. (*B.* Nov. 2, 1885.) Astronomer. Director of Harvard College Observatory. Astronomer at Mnt. Wilson Observatory. He has stated that the evidence in favour of a finite universe is no stronger than that in favour of an infinite one. He is the author of *Flights from Chaos* and *Star Clusters and Galaxies*.

SHARPEY-SCHAFER, Sir EDWARD A., F.R.S. (1850–1935). Physiologist. One of the pioneers in research on the endocrine organs and the part their secretions play in the manifestation of the emotions. As President of the British Association, in 1912, he advanced the new view that the origin of life took place, not in the primordial oceans, as almost all biologists believe, but in the upland fresh waters. His hypothesis, however, runs counter to too many known facts. It is in conflict, for instance, with the relatively high degree of salinity of the fluids in which the cells of our body and those of animals generally are immersed. (*See* Quinton.) Pub. *Quain's Anatomy*, *Advanced Physiology*, *The Endocrine Organs*.

SHERRINGTON, Sir CHARLES SCOTT, O.M., F.R.S. (*B.* 1861.) Waynfleete Professor of Physiology, Oxford (to 1936). Past President of Royal Society. Pub. *Mammalian Physiology*, *Integrative Action of the Nervous System*. The latter can best be described as a classic in the physiology of the nervous system.

SMITH, GRAFTON ELLIOT, F.R.S. (1871–1937). Past Vice-President, Royal Society. Professor of Anatomy, London University (1919–36). Comparative anatomist and anthropologist and a foremost authority on the comparative anatomy of the brain. Wrote widely on evolutionary subjects. Elliot Smith called the primitive part of the human brain, which is concerned chiefly with the sense of smell, the ARCHIPALLIUM. In the evolution of the pre-human brain a time came when it became advantageous to blend and co-ordinate the incoming impulses to the ARCHIPALLIUM from the nose with those from other sense-organs—eye, ear, skin, etc. This great co-ordinating network of nerve-cells (one of the latest products of Evolution), which makes up the principal part of the human brain, he called the NEOPALLIUM. He made a special study of the skull of Peking man, HOMO SINANTHROPUS, discovered by W. C. Pei, a Chinese geologist, at Chou Kou Tien, near Peking, on Dec. 2, 1929. SINANTHROPUS, Elliot Smith stated, is a generalized form intermediate between the ape-man, PITHECANTHROPUS, and Piltdown man, EOANTHROPUS. This ancestral Chinaman probably roamed the Western Hills flanking Peking, a million years ago, in the Pliocene period. Pub. *On Mummies*, *Evolution of Man*, *Essays on Evolution*, *History of Civilization*, *Peking Man*, *Human History*, *The Search for Man's Ancestors*.

SMITH, WILLIAM (1769–1839). English geologist. His geological survey of England led him to conceive the idea of a *definite and orderly succession of life*, as against the theory of Cuvier and his school, that the flora and fauna of each epoch were periodically destroyed by convulsions of nature, after each of which the earth

was re-clothed with vegetation and re-peopled with animals by a fresh creative act! It was Smith who placed in the hands of Sir Charles Lyell (1797–1875) the particular weapon that enabled him, when in 1830–33 he published his *Principles of Geology*, to give the death-blow to Cuvier's Catastrophic theory of the history of the earth.

SODDY, FREDERICK, F.R.S. (*B.* Sept. 2, 1877.) Lee's Professor of Chemistry, Oxford, 1919–36. One of our foremost authorities on radio-activity. Pub. *Chemistry of the Radio-Elements*, *Matter and Energy*, *Science and Life*, *Inversion of Science*.

SOLLAS, WILLIAM J., F.R.S. (1849–1936). Geologist and archæologist. Made special researches into the structure of the earth and on prehistoric man. Pub. *Age of the Earth*, *Ancient Hunters*.

SPENCER, HERBERT (1820–1903). The great synthetic philosopher. In 1852 he had written a paper giving a clear presentation of the general doctrine of Evolution, and in the *Principles of Biology* (1863–66) *First Principles*, and *Sociology*, he gave the theory of Organic Evolution a philosophic expression. He used the phrase "survival of the fittest," and it is marvellous how near he was to discovering Natural Selection. He gave his life to establishing the great principle of Evolution, and to applying it to physical, biological, psychological, and social facts. His works are a monument of genius and industry.

TENNYSON, ALFRED, Lord (1809–92). Poet laureate. If Lucretius was the first poet of Evolution, Tennyson certainly deserves to be called the last. He says:—

> "Many an Æon moulded earth before her highest, man, was born,
> Many an Æon too may pass when earth is manless and forlorn."

And again:—

> "Evolution ever climbing after some ideal good,
> And Reversion ever dragging Evolution in the mud."

He placed Man and his strivings in a true evolutionary perspective when he wrote:—

> "What is it all but a trouble of Ants
> In the gleam of a million million of suns?"

His insight into the method of Selection in Evolution is well shown in "So careful of the type she seems, so careless of the single life." [1]

THOMSON, Sir J. ARTHUR, M.A., LL.D. (1861–1933). Emeritus Professor of Natural History, Aberdeen. Wrote widely on Evolution in a very captivating style. Perhaps the two most famous of his works (written jointly with Patrick Geddes) are the earliest (1889), *Evolution of Sex*, and latest (1931), *Life; Outlines of General Biology* (2 vols.). His other writings include *Outlines of Zoology*, *Study of Animal Life*, *Herbert Spencer*, *Heredity*, *Darwinism and Human Life*, *Biology of the Seasons*, *Evolution*, *Wonders of Life*, *What is Man?*

TYNDALL, JOHN, F.R.S. (1820–93). Physicist. He was a great friend of Huxley and an ardent champion of Darwin. In his Presidential Address at the British Association, in 1874, at Belfast he said: "We claim and we shall wrest from theology the entire domain of cosmological theory." Tyndall made many original researches into the movements of glaciers. His *Heat as a Mode of Motion* and his *Fragments of Science* still make, despite the revolution caused by the "splitting of the atom," delightful and instructive reading. A charming Life of Tyndall has been written by A. S. Eve (1946). It well depicts his materialistic outlook.

VRIES, DE, HUGO. (1848–1935.) Dutch botanist. Emeritus Professor of Botany, University of Amsterdam. He initiated the theory of MUTATION as one of the methods of Evolution (a theory now generally accepted by biologists), conceiving the idea from observing "sports" in the Evening Primrose (*Œnothera Lamarckiana*). He proved that in this and other plants Evolution in many cases undoubtedly pro-

[1] As these lines were written before the publication of *The Origin of Species*, it will be seen that Tennyson, to a certain extent, anticipated Darwin's central idea.

gresses by sensible " jumps " rather than by gradual and imperceptible steps. Pub. *Mutation Theory*, *Species and Varieties*, *Plant Breeding*.

WALLACE, ALFRED RUSSEL (1823–1913). He travelled with Bates along the Amazon and made collections of natural-history specimens; sailed, in 1854, for the Malay Archipelago for the same purpose. When lying ill with fever at Ternate, in February, 1858, something led him to think of the " positive checks " described by Malthus in his *Essay on Population*. He says: " There suddenly flashed on me the *idea* of the survival of the fittest, and in the two hours that elapsed before my ague fit was over I had thought out the whole of the theory, and in the two succeeding evenings wrote it out in full, and sent it by the next post to Mr. Darwin."

It is remarkable that both Darwin and Wallace should have independently discovered the same theory, and have expressed it in almost the same words, and that they should have *suddenly* hit upon it in thinking over the same book. Darwin wrote an abstract of his *Origin*, which was read, with Wallace's paper, at a meeting of the Linnean Society on July 1, 1858.

WEISMANN, AUGUST (1834–1914). German biologist. Famous as being the first biologist to deal with heredity from a purely physico-chemical standpoint. His great thesis was the *continuity of the germ plasm*. Children resemble parents because they are made of the same material; the stream of protoplasm, represented by the chain of dividing germ-cells, passes on from generation to generation, and, like the ever-dividing protozoa, the germ-cells that form the links of the chain, or rather of a series of diverging chains, are, within the limits of the many million years since the dawn of life, immortal!

WELLS, HERBERT GEORGE, D.Sc. Lond. (1866–1946). First-class honours in zoology, Royal College of Science. Author of *Outline of History*, in which the story is told of our earth and its inhabitants since Palæozoic days. Joint author, with Julian Huxley and G. P. Wells, of *Science of Life*, a magnificently illustrated work that deals exhaustively with the complex body-machine of man and lower animals, and explains, so far as modern science permits, how it came to be, how it functions, and how it multiplies.

WIEDERSHEIM, ROBERT. Was Professor of Comparative Anatomy at Freiburg. He wrote *Elements of the Comparative Anatomy of Vertebrates* and *The Structure of Man*, both of which teem with interesting facts concerning man's evolution.

Such are a few of the great men whose toil has helped in interpreting the universe to man. When we have finally left our barbarism behind, instead of recording battles we shall mark our calendars by the life-spans of these pioneers " who battled for the True."

DARWIN IS DEAD; LONG LIVE DARWINISM.

## APPENDIX

### Atomic Bombs and New Stars

THE general principle underlying the production of the atomic bomb is by no means a recent discovery; it has been familiar to physicists the world over for many years. An eminent scientist, G. Gamow, Professor of Physics at George Washington University, wrote some significant words in his work *The Birth and Death of the Sun* published in 1940, which conclusively prove that an explosive mechanism of this nature had been clearly envisaged before he wrote his book:—

> "When struck by neutrons, these nuclei (of uranium and thorium atoms) are apt to split into two large parts, and this major breakdown is also accompanied by the ejection of smaller nuclear splinters in the form of two, three, and sometimes even four other neutrons. . . . *The proper treatment of these nuclear reactions may lead us to the possibility of the large-scale liberation of sub-atomic energy.* Two questions . . . arise, and the first concerns the reasons why a piece of uranium, when bombarded by neutrons in our laboratories, does not immediately explode, thereby wiping out the lives of the experimenters as well as of any other living beings within many hundreds of miles." (The italics are mine.)

The principle of the transmutation of matter into energy, that has made feasible the advent of the atomic bomb, should be credited to Albert Einstein; though, with characteristic modesty, he disclaims such credit. Nevertheless, while not expecting to see the release of atomic energy in his lifetime, he was convinced of its theoretical possibility. In support of his hypothesis of the mutual transformation of energy and matter, Einstein had, as chief witness, pure mathematics; but in subsequent years there has been forthcoming plenty of evidence in this direction from physical laboratories and astronomical observatories. It was Einstein who blazed the trail that led to the atomic bomb, and which, further pursued, will lead to such benefits as industrial power-plants, and sea and land transport, by means of energy set free from the heart of the atom, always assuming political interests do not interfere. The great scientist put his revolutionary conception into an equational nutshell: $E = MC^2$, where $E$ stands for the energy in ergs of a given piece of matter, $M$, expressed in grams; and $C$ represents the velocity of light in centimetres per second ($2{\cdot}997 \times 10^{10}$ cm. per sec.); hence $C^2$ is

approximately 898 trillion ($8{\cdot}98 \times 10^{20}$). Using this formula, we learn that a single gram ($15\frac{1}{2}$ grains) of matter can, by self-annihilation, create $8{\cdot}98 \times 10^{20}$ ergs, or, what is equivalent, 66·6 billion ($66{\cdot}6 \times 10^{12}$) foot-pounds of energy. To employ more homely units of measure, we may say that a single grain of matter, transmuted into energy, gives rise to over four billion ($4{\cdot}273 \times 10^{12}$) foot-pounds. Contrast quantitatively the ordinary energy of combustion, now made use of in our car cylinders and locomotive furnaces, with that which could be released from the interior of atoms. A ton of coal, completely burnt, would supply a little over 22,000 million ($2{\cdot}25 \times 10^{10}$) foot-pounds; by the annihilation of matter and its transformation into energy, this same weight of coal would provide just over sixty-seven trillion ($67{\cdot}3 \times 10^{18}$) foot-pounds. This means that sub-atomic power yielded by a given weight of matter, whether of wood, peat, gas, oil, coal, or what not, is 3,000 million ($3{\cdot}0 \times 10^{11}$) times greater than the power given out by the combustion of the same weight of these substances!

It will be well at this stage to pass in review some of the steps, following upon the discovery of the mutual transformation of matter and energy, that led to the discovery of that deadly piece of ordnance, the atomic bomb, which practically wiped out the towns of Hiroshima and Nagasaki. Some thirty-four years ago Lord Rutherford, then Sir Ernest, scotched the firmly held belief in the indestructibility of the atom by smashing it and laying bare its intestine parts. The hammer, or rather the projectile, with which he effected this feat was the core of the helium atom, better known as an alpha-particle. He, his pupil Blackett, and the Rutherford school generally, not only disintegrated atoms; they turned one kind into another, thereby fulfilling the dream of the old Arabian alchemists. They hit nitrogen with an alpha-particle, and lo! it became oxygen. But this alpha-particle, as a bombing agent, had a great drawback: it carried two positive charges, with the result that its penetrative power was seriously embarrassed by the pushes and pulls exercised on it by other charged particles it encountered in its path. In 1932 Chadwick, a collaborator of Rutherford, discovered another particle, which he drove out of beryllium by firing alphas at it; this new particle was the neutron, which proved to be a far more efficient splitter of atoms. While the alpha-particle is composed of four protons joined to two electrons, and which consequently carries two positive charges in virtue of its two unneutralized protons, the neutron is made up of a single proton and electron in close combination, so that it is a quarter of the weight of an alpha—for it is the protons that give atoms their mass—and is devoid of any

charge. Later, a still better way of obtaining neutrons was discovered, which consisted in making heavy-hydrogen nuclei, or deuterons, bump into one another, as a result of which collision each couple transmutes into a neutron and a light isotope of helium. When nitrogen is bombarded with neutrons it is turned into boron and helium. Though the base metals have not as yet been changed into gold, a step in that direction has been made by bombing platinum with neutrons. The platinum is first made radio-active, and after a few hours it turns into gold. From a financial point of view the whole transaction is about as profitable as selling half-crowns at sixpence apiece.

It was an Italian physicist, Enrico Fermi, who predicted some years back that the unstable and, relatively speaking, large nucleus of the uranium atom would be split into two more or less equal parts by a judicious bombardment. In the early stages of the recent war with Germany the prophecy was fulfilled. Two German scientists, O. Hahn and L. Meitner, by firing a salvo of neutrons into the uranium nucleus, broke it into two approximately equal pieces, which were tentatively assumed to be the nuclei of the atoms of boron and krypton. The collapse of the uranium nucleus may have been direct, or it may have been the end result of a series of disruption reactions.

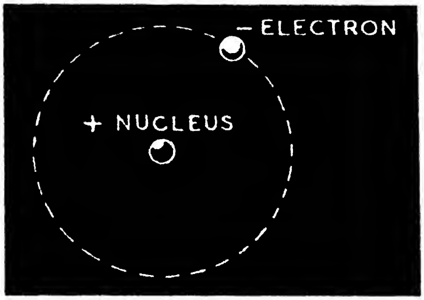
The disintegration of the atom, the transmutation of one element into another, and, above all, the mutual conversion of matter and energy, have thrown light on many secrets of both the microcosmic and macrocosmic worlds. The source of the seemingly endless outpouring of radiation from, and of the gigantic explosions within, the sun and luminous stars is in great measure traceable to the conversion of a portion of their matter into energy. Our sun, for instance, is radiating energy at the rate of 296 quadrillion ($296 \times 10^{24}$) foot-pounds per second, and this expenditure demands the destruction per second of 4·36 million tons of matter. But our sun is miserly by the side of such spendthrift stars as $\alpha$ Cygni or Mira Ceti. The energy poured into space by the latter, at its maximum period of brilliance, amounts to 9,590,000 quadrillion ($9{\cdot}59 \times 10^{30}$) foot-pounds per second. This colossal outpouring necessitates a sacrifice of 142,000 million ($1{\cdot}42 \times 10^{11}$) tons of its substance during the same unit of time. Our galaxy or Milky Way universe, containing 150,000 million ($1{\cdot}5 \times 10^{11}$) stars, each averaging the sun in mass, is creating energy, in the form of radiation, at the rate of forty-four sextillion ($44 \times 10^{36}$) foot-pounds each second, paying for this by the liquidation of 654,000 billion ($6{\cdot}54 \times 10^{17}$) tons of material.

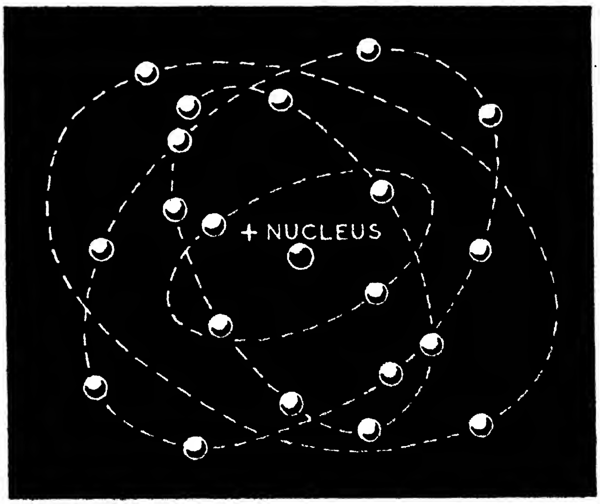
The universe, as conceived by Relativists, is finite in space and time.

It should be stated, however, that not a few eminent astronomers regard it as boundless and eternal. Some decline to commit themselves, and sit on the fence, so to speak, awaiting possible further astronomical developments. That great American astronomer, Harlow Shapley, says that the evidence in favour of a finite universe is no stronger than that for an infinite one. But the indisputable fact remains that to each successive depth the astronomer's plumb-line reaches, the answering cry is invariably "no bottom." In any case it would appear that the hypothesis of a universe that is boundless and timeless presents fewer difficulties of thought than a finite universe that commenced to exist at some time in the past. However, as the general principle of the conversion of matter into energy, and vice versa, is just as applicable to the one kind as to the other, we will assume the existence of a limited cosmos. The diameter of this, we are told, is of the order of 38,800 trillion ($3{\cdot}88 \times 10^{22}$) miles; this would give it a circumference of about 123,500 trillion ($1{\cdot}235 \times 10^{23}$) miles, to journey along which would take the fastest thing known, a ray of light, the velocity of which is 186,284 miles per second, 21,000 million ($2{\cdot}1 \times 10^{10}$) years to accomplish. The volume of this cosmic sphere is over thirty million decillion ($3{\cdot}058 \times 10^{67}$) cubic miles, and within this appallingly vast space are accommodated 500,000 million ($5 \times 10^{11}$) spiral nebulæ or galaxies or, as some term them, "island universes," each of which houses some 150,000 million ($1{\cdot}5 \times 10^{11}$) suns similar to our own. The total mass of matter in this finite universe, or cosmic sphere, amounts to more than 147 octillion ($147{\cdot}6 \times 10^{45}$) tons. Now, out of this total tonnage, over 300,000 quadrillion ($3{\cdot}112 \times 10^{29}$) tons are converted every second into twenty-one octillion ($21 \times 10^{48}$) foot-pounds of energy in the form of radiation. It is surely obvious that such wholesale destruction of matter going on throughout the whole universe must in time, despite the immensity of the reservoir from which it is drawn, result in the practical disappearance of matter from the cosmos, and its replacement by a universal blaze of radiation divorced from all material upon which it could shine, or confer heat, or do work of any kind. Apart from the theoretical evidence of the reversion of energy to matter, as set forth in Einstein's famous equation $E = mc^2$—apart even from the subsequent achievements of certain physicists—the Laws of Continuity, of the Conservation of Mass-Energy, of common sense and rational thought, one and all bear evidence to the high probability, amounting almost to certainty, that somewhere and somewhen in nature a compensatory process is at work making good the loss of matter and eternally preserving a balance between it and energy.

It will be well now to give attention to some of the findings and deductions of modern scientists as a result of their probings into the ultra-atomic worlds, and especially such as have been concerned with those reciprocal, yet correlated, modes of being, matter and energy. The fundamental units of radiation of all types, from those of longest wave-lengths, slowest frequencies, and feeblest energies (such as Hertzian waves, which include wireless waves) to those of shortest wave-lengths, of most rapid frequencies, and of most powerful energies (such as X-rays, gamma, and cosmic rays) are known as photons. These possess, as just indicated, manifold properties, but all have one thing in common—a velocity of 186,284 miles per second. Indeed they can only exist while travelling at this velocity; any arrest, or even slowing down, spells their death, as such, and from their dead bodies arises matter which takes the form, as a rule, of a positive or a negative electron. Should the photon strike a bright surface—polished silver or a mirror, for example—it rebounds with undiminished velocity but with a wave-length, frequency, and energy that may or may not have suffered alteration. Sometimes a high-energy photon, such as a gamma-ray, collides with a free electron. If the impact was a glancing one, the electron moves off in one direction, while the photon—with the same velocity, but with lessened energy equal to the amount it gave up to the electron—moves off in another direction. Supposing, however, the photon makes a direct or " head-on " collision with an electron, it then loses a part—possibly all—of its velocity, at the same time being compelled to turn itself into an electron. Just as photons lose their identity and change into matter if they suffer loss of velocity, so electrons lose their identity and change into energy if their velocity should become speeded up to that of light—186,284 miles per second. Occasionally a photon hits a planetary electron—that is, one of the electrons revolving in an orbit around the nucleus of an atom. The number of these orbits varies according to the kind of atom. In the simplest and lightest atom, hydrogen, there is only one electron that revolves in a single concentric layer, or " shell," as it is technically called; in the most complex and heaviest atom, uranium, there are as many as seventy orbits, which are arranged in seven shells. Several things may happen if a photon collides with a planetary electron. The latter may receive such an access of energy from the photon that it is " bumped up " into a higher—that is; more external—orbit; it may even be thrown out of the atom altogether, to wander about in space as a free-lance electron owing no allegiance to any atomic system. The photon, after collision, may rebound from the planetary electron in a fresh direc-

tion and with no loss of velocity; or the impact with the planetary electron may have lowered its velocity so that it turns into an electron which may actually replace the very one it expelled from the atom. Again, it may happen that some exceptionally energetic photon—such as the short-wave high-frequency gamma-ray that is ejected from the radio-active element, thorium $C\pi$—succeeds in threading its way past all the planetary electrons and boring itself into the very heart of the atom. Here, of course, its velocity is slowed down, with the result that it has, perforce, to become matter. The form this matter assumes is dependent upon many circumstances, chief of which is the energy-value of the photon on impact with the nucleus. It may turn into an ordinary or negative electron, or into a positive electron, which is much like the negative in size and mass, but is oppositely charged; or, finally, it may become converted into what is termed an electron-positron pair. The life of this last-named couple is exceedingly short—only about the one-tenth of a thousand-millionth ($10^{-10}$) of a second, after which lapse of time it turns back to a photon. Conversely, when a high-velocity positron clashes with a similarly endowed electron, an electron-positron pair is produced which almost at once turns back to a photon. It is significant, as endorsing the truth of the conservation of mass-energy, that the photon, or radiation, which transmutes into an electron-positron pair, or that is the transmutation-product of such a pair, possesses exactly twice



the amount of energy of the radiation, or photon, that transmutes into a single positron or electron, or that is the transmutation-product of a single one of these entities. We have seen the extent to which the sun and stars are constantly drenching space with radiations—that is, with photons. If space were an absolute void, a perfect vacuum, the photons rushing hither and thither through it would have to depend upon collisions with gross matter such as luminous or dark stars, nebulæ, etc., to get their chance of reverting to matter; and such bodies, even in the most congested parts of a galaxy, are separated by enormous distances. Inter-stellar space (which lies inside the galaxies), as well as, though to a much lesser extent, inter-galactic space (which lies between the galaxies), contains many free sub-atomic particles, from electrons and positrons to protons and neutrons, as well as free nuclei, atoms, and even molecules such as cyanogen (CN). Such particles, in their entirety, afford many opportunities for the arrest of photons and their transmutation into matter. Needless to say, they are few and far between, otherwise the light of distant stars, despite their minute size, would be quenched; nevertheless, their numbers are sufficient for them to act as efficient agents in maintaining the matter-energy balance throughout the cosmos. Two astrophysicists, O. Strive and T. Dunham, have calculated the number of certain atoms and molecules in each cubic metre of inter-stellar space. Taking a mean of their results, the number of these particles per cubic yard of inter-stellar space approximated: 7·8 million for the hydrogen atom, 1,300 for the carbon, 65 for the sodium, 13 for the potassium, and 2·6 for the calcium atom; for a molecule of cyanogen (CN) it was 1·3. From the above it will be seen that, while the annihilation of matter, with the consequent creation of energy, takes place principally in the depths of hot stars, the transmutation of energy into matter occurs in the depths of space. In all such transformations the sum-total of matter and energy remains constant; there is no creation out of, nor annihilation into, nothing. Only is there change.

All unstable stars that manifest explosive characteristics are really atomic bombs on a cosmic scale. Those masses of blazing gases, the prominences of the sun, that are sometimes shot out to heights of 135,000 miles above its surface, are in all probability the end-result of the deep-seated release of energy from atomic nuclei. But the stars that are pre-eminently of the "atomic bomb" type are: (1) New stars, or Novæ, such as Nova Aquilæ and Nova Cygni; (2) Supernovæ, like that which exploded in August, 1885, within the great extra-galactic nebula, Andromeda; (3) pulsating stars, or Cepheid Variables, with Delta Cephei as

the type; (4) Giant Red long-period variables such as Mira or Omicron Ceti; (5) explosive stars of the kind that is supposed to have originated the Crab Nebula; (6) the star or stars at the core of planetary nebulæ; (7) stars with expanding atmospheres, such as the Cygni, and the rather unique and rare Wolf Royet stars represented by P. Cygni. The chain of events that culminates in these terrific stellar outbursts is very intricate and still largely a matter of conjecture and controversy among astrophysicists; but we will make an effort to follow it as best we can. The real starting-point of these explosions is in the central depths of the star, where temperature and pressure are extremely high, the former from fifteen million to thirty million degrees Centigrade; the latter, in some stars, exceeding 10,000 million earth-atmospheres, or 65½ million tons on the square inch. The net result of these two factors is that the atoms of matter are stripped of all their planetary electrons, and their naked bodies, the nuclei, are squeezed by the surrounding pressure into very close proximity; and this despite the strong repulsion they exercise on one another in virtue of their lost negative planetary electrons and consequently their acquisition of positive charges. At the same time these nuclei are subjected to a terrific bombardment from all sides by sub-atomic projectiles liberated from other atoms and nuclei, especially electrons of both kinds, protons, neutrons, and photons. This causes the disintegration of numbers of nuclei and the liberation of their component particles; but it means more than this—it means the transmutation into one another of some of the lighter chemical elements with the freeing of a certain amount of energy, also the direct transmutation of sub-atomic particles into energy. The whole stellar interior becomes a seething cauldron of various particles and photons. Overlying material arrests them, with the result that the photons revert to matter, and so the process is repeated over and over again, matter transmuting into radiation, and radiation into matter, the changes advancing at each stage a step nearer the surface. The time comes when the general turmoil reaches the sub-surface zones of the star; the pent-up energy blows away, as vaporized gases, great areas of this surface into distant parts of the stellar atmosphere, and at the same time radiations, or photons, representing a part of that energy, speed on at the velocity of light into the most distant corners of the universe. There are many transmutations that result in the liberation of energy in the form of radiation, or photons. For example, a gamma photon is set free during each of the following transformations:—

(1) The union of four hydrogen atoms to form one helium atom;

(2) The bombardment of lithium by a proton, and its transmutation into helium;

(3) Bombardment of boron by a proton, and its conversion to light-carbon;

(4) Bombardment of heavy-hydrogen by a proton, and its resulting conversion to light-helium;

(5) Bombardment of beryllium by helium, and its transmutation into heavy-carbon;

(6) Bombardment of normal carbon by a proton, and its change into light-nitrogen;

(7) Bombardment of heavy-carbon by a proton, and its transformation into normal nitrogen;

(8) The formation of light-oxygen after bombardment of a normal nitrogen atom by a proton;

(9) The conversion of normal into heavy-aluminium by bombarding the former with a neutron;

(10) The turning of ordinary copper into heavy-copper by neutron-bombardment;

(11) The turning of normal gold into heavy-gold by neutron-bombardment;

(12) The transmutation of normal uranium into heavy-uranium by neutron-bombardment;

(13) The bombardment of normal hydrogen by neutrons, and its conversion into heavy-hydrogen;

(14) The transmutation of heavy-hydrogen into light-helium by bombardment of the former with protons.

The reverse process, the creation of matter from photons, or radiation, may be illustrated by three transmutations:—

(1) The bombardment of an electron by a gamma photon results in the disappearance of the photon and the arrival of a second electron;

(2) The normal beryllium nucleus, bombarded by a gamma photon, transmutes into a neutron and a heavy-beryllium nucleus;

(3) Heavy-hydrogen, when bombarded by a gamma photon, transmutes into a proton and neutron.

When an explosion takes place in a star the outward and visible effects vary considerably. In the vast majority of cases the gas clouds resulting from the upheaval are uniformly distributed around the star; such was the case with Nova Aquilæ. Or the luminous clouds and

vapours may be unsymmetrically disposed, as though the explosion had been confined to one hemisphere; Nova Persei is a typical instance. An almost unique result of an explosion in a star is that presented by Nova Herculis. It is of exceptional interest, as bearing analogies to the fission of the uranium (U. 235) nucleus effected by Hahn and Meitner. Nova Herculis suddenly appeared in the sky on December 12, 1934. Careful observation revealed the astonishing fact that the star had, apparently, been blown into two parts by the force of the explosion. The two fragments steadily receded, the one from the other, at a velocity that, by February, 1937, had resulted in a separation of 0·6 angular seconds.

Natural questions that arise in one's mind are, first, Is our sun a youthful, middle-aged, or senile member among the Milky Way host of stars? and, secondly, Is there any likelihood, in the near future, of his suddenly going berserk and running amok as a nova in a mass of flame and fury? The standard example of an ancient dying star is Proxima Centauri, which happens to be one of our nearest neighbours, 25,000,000 million ($25 \times 10^{12}$) miles away from us; it is a member of the triple star Alpha Centauri. Let us consider briefly the possible evolution of our sun in the past and future. Starting as a miniature nebula, a wisp of gaseous matter detached from the mighty spiral nebula that eventually gave rise, by many millions of similar localizations of its material, to the stars composing our galaxy, or Milky Way, this nebula then began to contract, and at length took definite form as a Giant Red star, not unlike the Red Giants Betelgeuse and Antares. Contraction continued apace, while at the same time temperature and density rose, and our ancestral sun passed through a number of phases until it arrived at a Giant Blue Star stage, of which Rigel is a good representative. After this, temperature began to fall owing to excessive radiation, but contraction and rise of density continued. At length the sun reached its present position, which is that of a Main Sequence Yellow Dwarf, G, star. Much of its radiation energy is now, as we have seen, dependent upon transmutations of atoms and sub-atoms into photons; possibly still more of its radiation is at the expense of its abundant hydrogen, which is being lavishly turned into helium. When the sun becomes bankrupt in hydrogen this particular source of energy will no longer be available, and our orb may then contract to a dense White Dwarf star resembling the small companion of Sirius known as Sirius B. In doing so, however, it may in its death-throes—for the White Dwarfs are regarded as decadent stars—suddenly burst forth as a Nova and become a subject of widespread internal convulsions which, reaching the exterior, will push out its

fiery atmosphere to distances that will roast the surfaces of all the planets and expunge every living thing from the face of the earth. Many astronomers believe this catastrophic White Dwarf stage to be already threatening our sun; but as they are speaking in astronomical terms, where a million years are but as a day, we may leave all worry on this point to our far-distant descendants. The older view of the earth's last days was an ice-bound lifeless surface such as that of the present Jupiter; the more modern view is that of a burnt-up surface. Sooner or later, following on further contraction and loss of heat from the fierce radiation, this White Dwarf sun will turn into a yellow Sub-Dwarf. For a brief while it is conceivable that life of a low grade may again evolve in any waters left on the globe, but only to be extinguished after a few million years by the now increasing cold. There may be very slight spasmodic outbursts of renewed heat as one by one the planets and satellites fall into the sun; but very shortly, comparatively speaking, the sun will become an insignificant Red-Dwarf star. Finally, the light of this will be extinguished, and here we will leave our once glorious sun to pursue its path through the cold abysses of space until some event or other—possibly collision with another star; possibly the explosive transmutation of its dying atoms into radiation—enables it to arise, phœnix-like, from what remains of its ashes.

# BOOKS RECOMMENDED

## Popular. For General Readers

*A B C of Evolution.* Joseph McCabe. (Watts.)
*Age of the Earth.* Arthur Holmes. (Benn).
*Atom, The.* E. N. da C. Andrade. (Benn.)
*Atoms, Stars and Nebulæ.* Leo Goldberg and Lawrence Aller. (Blakiston.)
*Between the Planets.* Fletcher C. Watson. (Blakiston.)
*Birth and Death of the Sun.* George Gamow. (Viking Press.)
*Call of the Stars.* John R. Kippax. (Putnam.)
*Childhood of the World.* Edward Clodd. (Kegan Paul.)
*Concerning Man's Origin.* Sir Arthur Keith, F.R.S. (Watts.)
*Courtship of Animals.* W. P. Pycraft. (Hutchinson.)
*Creation by Evolution.* Collective. Ed. by Frances Mason. (Macmillan.)
*Darwinism.* A. R. Wallace. (Macmillan.)
*Darwinism and Human Life.* Sir J. A. Thomson. (Hutchinson.)
*Darwinism and the Problems of Life.* Conrad Guenther. Tr. by Joseph McCabe. (A. Owen.)
*Darwinism and What It Implies.* Sir Arthur Keith, F.R.S. (Watts.)
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*Evolution of Sex in Plants.* J. M. Coulter. (University of Chicago.)
*Evolution of the Horse.* F. B. Loomis. (Marshall Jones.)
*Evolution of Vertebrates.* William Patten. (Blakiston.)
*Extinct Plants and Problems of Evolution.* D. H. Scott, F.R.S. (A. & C. Black.)
*First Book of Organic Evolution.* D. K. Shute. (Open Court.)
*Footprints of Early Man.* D. A. Mackenzie. (Blackie.)
*From Atoms to Stars.* Martin Davidson, D.Sc., F.R.A.S. (Hutchinson.)
*From Monkey to Man.* L. H. Dudley Buxton. (Routledge.)
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*Geology.* Sir P. Geddes and Sir A. Thomson. (Thornton Butterworth.)
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*Mentality of Apes.* W. Kohler. (Harcourt and Brace.)
*Milky Way, The.* Bart. J. and Priscilla F. Bok. (Blakiston.)
*Mutation Theory.* Hugo de Vries. (Open Court.)
*Nature of Man.* Elie Metchnikoff. (Heinemann.)
*Origin and Nature of Life.* Benjamin Moore, F.R.S. (Thornton Butterworth.)
*Our World and Us.* A. G. Whyte. (Watts.)
*Pedigree of Man.* Ernst Haeckel. (Bonner.)
*Savage Survivals.* J. Howard Moore. (Watts.)

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*Stars in their Courses.* Sir James Jeans, F.R.S. (Cambridge U.P.)
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*Within the Atom.* John Mills. (Routledge.)
*World's Wonder Stories, The.* A. G. Whyte. (Watts.)

## More advanced Books, but not over-technical

*Animal Biology.* J. B. S. Haldane and J. S. Huxley. (Oxford U.P.)
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*Arboreal Man.* F. Wood Jones. (Arnold.)
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